White Paper

Grant Number PF-255866-17

To Plan the Renovation of Philbrook Museum of Art's HVAC System

Project Director: Rachel Keith, Deputy Director for Audience Engagement & Curatorial Affairs

Philbrook Museum of Art

Submitted March 31, 2019

Philbrook

Project History

Philbrook Museum of Art is a 20,000 square-foot Italianate Villa located on 25 acres of landscaped gardens. Designed by architect Edward Buehler Delk (1885-1956), the historic Villa was built in 1926 for petroleum businessman Waite Phillips and his family, then generously donated to the community in 1938 to become Tulsa's first art museum.

The historic Villa, where the permanent collection is displayed, is a 30,000-square foot stucco building with a clay tile roof. The Museum's historic building is listed on the National Register, with an 80,000 square-foot wing constructed in 1989. While the Villa itself forms the heart of the Museum, the newer wing includes the main entry, 5,000-square-foot exhibition gallery, offices, six collections storage areas, and education classrooms. Overall, the building is in very good condition, but the HVAC system has far exceeded its expected lifespan. The primary system components are approximately 40 years old, and while the heating and cooling systems are still operating near capacity, humidification capacity is only at 50%. Over the past few decades, the Museum's HVAC system has been patched together in a reactionary and opportunistic way to fit within available parameters of income or support. The largest current threat to the preservation of the historic property and permanent collection is the building's antiquated and unreliable HVAC system.

Project Activities

Through the support of a National Endowment for the Humanities Sustaining Cultural Heritage planning grant, Philbrook Museum of Art has completed a cross-disciplinary study of the Museum's outdated HVAC system in advance of a long-overdue system replacement. The study's goals were to support the integration of sustainable practices into Philbrook's strategy for environmental control and to identify ways to balance the needs of the Museum's permanent collection with the needs of Philbrook's historic Villa, which—as a Historic Structure Report from 2009 indicated—are oftentimes at odds. Through this project, Philbrook engaged a team of experts including conservators, curators, engineers, and sustainability consultants, to plan proactively for the HVAC system replacement by applying the latest research in sustainable approaches to climate control and preventative conservation. The project team developed both a broad approach and a specific set of recommendations to improve collections care and sustainability across the institution.

In November 2017, Philbrook launched the grant project with a day-long site visit with the full project team, including: Sarah Sutton, Museum Sustainability Consultant; Rachael Arenstein, Objects Conservator; Dianne Modestini, Paintings Conservator and Director of Kress Conservation Program; Guy de Verges, Environmental Engineer; Charisse Cooper, Philbrook Facilities Manager; John Gwin, Philbrook Lead Engineer; Jaye McCaghren, Philbrook Collections Manager; Catherine Whitney, Philbrook Chief Curator; Christina Burke, Philbrook Curator of Native American Art; Sarah Lees, Philbrook Curator of European Art; Susan Green, Philbrook Curator of Special Collections; and Rachel Keith, Project Director and Philbrook Deputy Director of Audience Engagement & Curatorial Affairs.

The project was divided into five phases that included an initial site assessment by expert consultants to review existing conditions and conduct system and building inspections, followed by a series of meetings to review their findings and recommendations.

During the first site visit, the project team became familiar with the building, its existing systems and issues, and identified questions and opportunities to explore over the course of the project. The team analyzed records, including eight years of temperature and relative humidity charts, seven years of archived utility statements, various structural and collection-focused reports, artwork examinations and conservation histories, and on-site inspections.

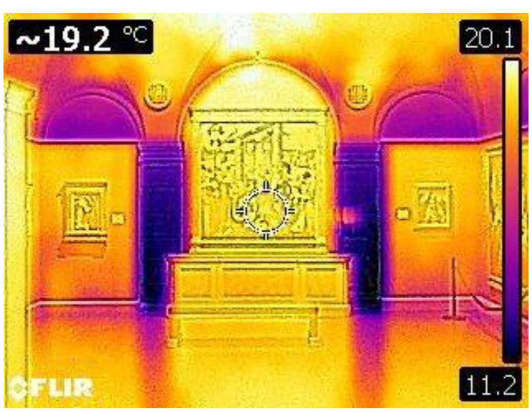
Over the course of three more meetings—held onsite for local participants and virtually for those out of town—the project team shared findings from their own interim research and identified areas and questions requiring further exploration.

Project Accomplishments

The primary goal of the project team was to maximize energy reduction while supporting an optimal climate for both Philbrook's collection and its historic structure. The team recognized early in the project that achieving this goal would require more than just replacing the building's HVAC system. Working together, the team identified the following: (1) opportunities to reduce the load on the HVAC system, including better sealing the building envelope, completing the transition to LED bulbs in galleries, and using carbon dioxide from building inhabitants rather than outside air as a source for make-up air; (2) ways to incorporate passive approaches to environmental controls; and (3) appropriate steps to care for the building fabric, such as eliminating opportunities for condensation—steps that will also help preserve the building itself.

The team also identified key locations where, over decades, Museum staff has asked the building to function in ways it was not intended. As a result, the building has suffered, with mold growing around poorly sealed windows, and leaks persisting undetected beneath drywall covering original windows. The most extreme example of this is in the Kress Galleries, a series of rooms originally built as a sunroom and open-air porches, enclosed in the 1950s to create a home for a collection gifted to the Museum by the Kress Foundation. Metal-framed windows were installed between limestone columns and then drywalled over from the inside. Although a minimal layer of insulation was installed, no vapor barrier or thermal break was put in place. As the porous columns wick moisture from the outside of the building into the inside and as condensation from the warm gallery spaces collects on the interior of the cold metal window frames, the drywall frequently becomes wet, causing mold growth and material degradation.

These findings can be seen in the sustainability report by de Verges & Associates. Following the site visit in November, de Verges conducted thermal imaging of the historic Villa. *(See Appendix D for de Verges & Associates' Sustainability Report.)* His report included indicated the following: (1) moisture within the lower Kress Gallery is composed of not only condensation, but also the moisture that is being wicked through the limestone columns whenever the exterior of the Villa is wet causing pockets of increased relative humidity around the artworks on the wall; (2) the lack of insulation between the windows and covering sheetrock cause the adjacent art to become warmer than their surroundings, including a 10-degree difference between two art works within the American Gallery; (3) an active leak in the Villa's Santa Fe Room is being caused by an active leak; and (4) all doors should be evaluated for air leakage. These findings are illustrated in de Verges' report following his thermal imaging of the structure and illustrated in the following photos.



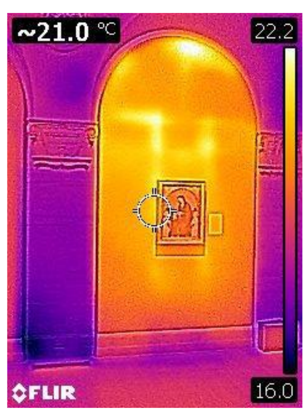


Photo 1 (left): Thermal image of the Kress Gallery, the columns appear purple, indicating moisture.

Photo 2 (right): Thermal images of covered Villa windows illustrating how the metal frames of the windows heat with sunlight.

Philbrook is well aware of the mandate in the field—both nationally and globally—to improve energy efficiency in maintaining appropriate environments for collections. In the past several years, new environmental guideline statements have been issued by the IIC and ICOM-CC, AICCM, the Bizot group, and the AIC with support from the AAMD endorsing broader ranges of acceptable climate settings. In order to increase system efficiency by loosening system setpoints, Museum staff needed first to better understand the needs of the collection. Rachael Arenstein, conservation consultant on this project, reviewed the condition and condition histories of a portion of the Museum's most sensitive items, several previous years of Museum climate data, and completed a survey of both published and soon-to-be-published museum climate recommendations, including the Image Permanence Institute's *Guide to Sustainable Preservation Practices for Managing Storage Environments* (v.2.0, 2012), British Standards Institute document PAS 198:2012: *Specification for Managing Environmental Conditions for Cultural Collections*, and Chapter 23 of the *American Society of Heating Refrigerating and Air-Conditioning Engineers Handbook—Heating, Ventilating, and Air-Conditioning Applications*, among others.

Rachael Arenstein, conservation consultant for this project, provided clarity for establishing clear set points by providing Philbrook with a detailed recommendations report specific for Philbrook's collections (*Appendix F*). This research identified target relative humidity setpoints as 45% in the winter and 50% in the summer, with an absolute minimum of 30% and maximum of 60%. Keeping the relative humidity as stable as possible and allowing the temperature to fluctuate somewhat in order to support stable humidity is also now a priority for the system. Temperature setpoints will be set as low as possible while maintaining human comfort, around 68-70 degrees Fahrenheit in galleries, with lower temperatures maintained in storage areas as practicable. The lowest level storage areas are ideally situated to efficiently support a cool (around 54 degrees Fahrenheit) storage environment. They have excellent buffering capacity, as they are situated underground, with thick concrete walls and tightly sealed access points. During previous periods of equipment malfunction, the climate has not changed significantly in these areas.

Other storage rooms on the ground level will be kept somewhat higher, around 64-68 degrees Fahrenheit. Renovations to storage rooms are planned as a capital project, and subsequently the collection would be rearranged to take advantage of cooler storage for the highest-risk materials, including photographs, works on paper, and organic and inorganic 3D objects. These setpoints have been identified not only to better support the collection, but also to mitigate potential damage to the historic building fabric caused by condensation from unnecessarily high humidity inside the building during cold weather.

Additionally, a report from Sara Sutton, museum sustainability consultant, provided valuable feedback and instruction on sustainability thinking. This report, located in *Appendix G*, is a valuable resources for ensuring all team members and observers have the opportunity to mature in the understanding, support, and implementation of sustainability choices in general, and specifically during future phases of this project.

At the close of the grant project, Philbrook compiled the recommendations of each expert consultant for the Museum's HVAC system renovation. A summary of recommendations resulting from the planning grant is available in *Appendix H*. Highlights from these recommendations include:

1) Stabilize the system by replacing failing components with high-efficiency, durable equipment.
2) Aim for stable humidity in the range of 45% +/-10 (winter) and 50% +/-10 (summer).
3) Float temperature to keep humidity stable rather than adjusting humidity to stabilize temperature.
4) Employ a centrifugal chiller.
5) Re-establish redundancies within the system.
6) Aim for lower temperatures in storage.

7) Prioritize relative humidity stability over temperature.

Next Steps

The findings of this project were crucial in influencing Museum staff to work with the building, its limitations, and its climates—a much more sustainable approach than working against it. Following the initial site visit and consultant reports, Philbrook staff determined that a larger reevaluation of the use of the Kress Galleries and related spaces would be necessary before proceeding, and shifted the timeline for project completion accordingly. Because this area of the historic structure was previously a sunroom and series of porches, it has a lack of insulation that results in unstable conditions for the works within the space. Confirmation of these issues from project consultants has subsequently influenced Philbrook staff to decide to revert these gallery spaces closer to their original design and use, which in turn means that the Museum must determine new gallery space for the collection. Precise details will be determined during the design development phase of an upcoming capital projects campaign, but the Museum intends to uncover the sealed French doors; replace the 1950s-era metal-framed windows with historically appropriate wood-framed, double- or triple-glazed windows; and relocate the highly sensitive panel paintings currently displayed there to other gallery spaces where the climate can be stabilized more consistently and efficiently.

Throughout the building, a number of windows currently covered with drywall or other materials will be uncovered during future renovation to better connect the galleries with the gardens, provide visitors with a clearer sense of place within the galleries, and promote better care for the building by allowing access for regular inspection, maintenance, and repairs as needed. During the same renovation, all windows will be fitted with interior ventilated wooden storm windows with UV protection. Although increased light levels in certain galleries will limit the works that can be displayed there, the improved care of the building and visitor experience will more than compensate for this new challenge, and several areas within the building will still offer very low light levels for light-sensitive artworks.

Based on the recommendations of the planning team, Philbrook staff and consultants have designed a two-phase project to (1) stabilize the system and gather more detailed climate readings, and (2) refine the system and implement operational efficiencies. Phase One will involve replacing the major system components located in the boiler room (two steam boilers, two hot water boilers, two chillers, one heat exchanger, two chilled water pumps, and two heating water pumps). In addition to replacing these components, Museum staff will implement comprehensive monitoring throughout collection storage and display areas to build a more complete picture of microclimates within the building. At the end of Phase One, the primary components of the HVAC system will be operational, with redundancy restored, and more than one year of climate data will be available to guide planning for Phase Two, which would involve any needed changes to ductwork, airflow, air handling units, additional humidification, and a new building automation system that would support increased flexibility and operational efficiency.

Lessons Learned

Through the course of this project, the team recognized the need for support from experts more specialized in managing museum clients than the current project team included. After speaking with project advisors and the Image Permanence Institute (IPI) staff, the Museum enlisted IPI conservator Kelly Krish and facilities specialist Chris Campbell to consult on the next phase of the HVAC project. In addition to IPI consultants, the Museum has also contracted with a mechanical engineer and certified Building Commissioning Professional at Cyntergy, a local engineering firm, to confirm all future equipment installations are completed according to the highest standards. Philbrook has also established a cross-departmental team for monitoring and managing the environment and adopting environmentally sustainable practices broadly across the institution as a result of this project.

The conversations that resulted from consulting with a broad cross-disciplinary group were beneficial for all members of the project team. While team members started with drastically different familiarities with “green” practices and collections care, by the end of the project, the group as a whole increased their understanding of opportunities to improve the care and efficiency of the building and the environmental needs of the collection.

de Verges
& ASSOCIATES
air water soil

November 20, 2017

Rachel Keith
Director of Collections and Exhibitions
Philbrook Museum of Art
2727 S. Rockford Rd.
Tulsa, OK 74114

Re: HVAC/Sustainability Grant

Dear Ms. Keith:

Thank you for the opportunity for de Verges & Associates Environmental Consulting, Inc. (de Verges) to assist Philbrook with your HVAC/ Sustainability Grant review and museum inspection. During our meetings, you indicated you wanted de Verges to focus on the moisture issues with the Kress galleries and HVAC improvements.

de Verges work on these topics began on the November 6, 2017 daylong meeting and inspection of the museum as part of the interdisciplinary team meeting and a follow-up site visit on November 9, 2017 to conduct a more detailed inspection of the Kress gallery with a Flir Thermal Imaging Camera and moisture detection meter.

The project budget allotted to de Verges for this project did not allow enough time for a complete Energy Efficiency investigation or Sustainability plan so we focused our consulting time on the Kress gallery issues and general sustainability/HVAC goals.

Kress Gallery Inspection and Observations:

During the November 6th meeting and museum tour, much discussion was placed on issues with the Kress gallery objects located on the museums 1st floor south end. Museum staff indicated that they were concerned with moisture and Relative Humidity (RH) impact on the artworks contained in this wing of the museum.

The Kress Gallery is located in an area of the museum that was originally an open covered porch or sun room with Kasota limestone floors, columns, and stucco walls. The sun room was expanded in 1933 with the addition of the south terrace which was also an open covered structure constructed in the same manner as the sun room. These areas of the original house were open to the environment. In 1941, after the home had been donated to the Southwest Art Association and converted into a museum, the sun room and south terrace were enclosed to allow for more gallery space. The original openings of the sun room were updated and filled in with walls, metal windows and metal doors.

During the November 6th tour of the Kress Gallery, staff indicated moisture and mold issues had developed around the SW covered openings of the South Terrace **(Photo 1).** Staff were concerned the aforementioned issues were impacting the displayed artwork on the west wall. After further investigation of this area by de Verges the following issues were identified:

A. **Sun Room Limestone Columns Observations -** The limestone columns of the sun room are porous due to the indicating dissolution features of the rock and matrix material. The columns **(Photos 2 & 3)** are exposed to moisture from the outdoor environment as well as the villa irrigation system. During our site

visit we noted that some of the western columns were moist **(Photo 4)**; however, all of the columns were cold in comparison to the indoor ambient temperature.
Any moisture, absorbed on the exterior of the columns, will move to the opposite side of the column in the interior of the building by molecular diffusion and will eventually evaporate inside. Another possible source of indoor column moisture could be a result of condensation occurring on the face of the columns. This occurs when the indoor environmental conditions of temperature and Relative Humidity (RH) interact with the cold surface temperature of the columns. **Photos 5 & 6** are infrared images of the same area as **Photo 1**. The image shows nearly a 10 degree Celsius (dark blue to purple areas are colder and yellow to orange are warmer) difference between the ambient temperature and the base of the column. At 50% RH, the temperature of the column base is close to the dew point on the day we inspected this area.

No matter the source, elevated moisture was detected in some of the columns, as well as in the wallboard that comes into contact with the west columns. We believe the moisture in the wallboard is being absorbed from the columns. The moist wallboard is susceptible for organic growth and as the moisture evaporates, this process may allow for the art to absorb said moisture from the wallboard.

Sun Room Limestone Columns Recommendations:

- All organic material (bedding plants, grasses and trees) should be trimmed away from the building to leave a minimum 18” of air space around the Philbrook buildings. This is to allow the columns and other building materials to dry in-between rain events. This air space should be checked quarterly as part of a building preventive maintenance system.
- All irrigation heads, near the building, should be removed to eliminate saturation of the columns from lawn irrigation. On a quarterly basis, as part as part of a building preventive maintenance system, the remaining irrigation head spray patterns should be checked to insure the building is not being wetted during lawn irrigation.
- Research should be conducted to find a clear, water proofing sealer that could be applied to the exterior of the columns exposed face to <u>minimize</u>, not eliminate, absorption of water from the outside environment.
- Porous building materials, such a wallboard, should never be in direct contact with the column. If contact is required, the column contact area should be sealed and a non porous thermal break material should be applied between the two materials.
- Porous art objects should not come in contact with the limestone columns. Any art attached to the wallboard, that contacts the exterior columns, should have an air space behind the object to allow for an appropriate amount of air flow that <u>minimizes</u> the impact of dew point related condensation.

B. **Windows of the Sun Room and Villa** – Thermal imaging of the covered windows in the sunroom indicate there is little or no insulation and that no thermal break exists between the metal window frame and interior wallboard. The purple color of the window arches in **Photos 5 & 6** indicates a colder temperature than the surrounding area. The reverse is also evident in **Photo 7** on the east side of the sun room that is exposed to direct sunlight. In the thermal image you can see the metal framework of the window. Artwork attached to covered windows would be exposed to much larger temperature swings than artwork not attached to covered windows. **Photo 8** is of artwork attached to the wallboard covering an east, upstairs window located in direct sunlight. You can see the significant temperature and thermal radiation difference the two side by side artworks are experiencing. <u>This environment may be impacting the stability of the artwork.</u> These issues should be evaluated by an art expert for further consideration.

Windows of the Sun Room Recommendation:

- All sunroom and villa windows, as well as original window openings in the sunroom should be evaluated for repair. The metal windows in the sunroom should be replaced with modern thermal windows that have either double or triple glazing with argon filled air gaps. An appropriate glazed coating should be applied to eliminate infrared radiation and minimize solar heat gain on south facing windows. If metal windows are selected as replacement, they must have a thermal break between the window frame and the building structure connection.

  The filled in original window openings in the sunroom should be opened from the interior of the building for inspection. The openings should be evaluated for structure and moisture intrusion. Repairs should be made at this time as required to maintain the structure and moisture control. The opening should then be air sealed and insulated by applying closed cell foam insulation to the opening, as well as a radiant barrier with an appropriate air space. The opening can then be closed with wallboard. The wallboard and any structure for the wallboard must have a thermal and moisture break between the limestone and the porous building materials.

  The closed, double hung wood windows on the second floor gallery should be returned to service with interior storm windows that allow air movement between the storm window and the wood window. The storm windows should be coated to eliminate infrared heat gain. The same type of interior storm windows should be installed on all villa wood windows. The exterior storm windows and glass films applied to some windows should be removed during this process.

  All wood windows should be inspected for air gaps and paint **(Photo 9)**. All wood windows should be inspected for defects on a quarterly basis, as part as part of a building preventive maintenance system.

Other Villa Observations - Santa Fe Room Moisture Issues:

While this room was not directly part of the sustainability study goals, we noted an active leak in the NE corner of the Santa Fe Room as noted in **Photo 10**. The very dark blue in the corner of the room appears to be an active leak in the building exterior. This moisture was identified with the hand held moisture detector. Further investigation of this issue should be conducted and may be impacting art in this area of the museum.

Energy Efficiency, Sustainability and HVAC Improvements

Energy efficiency of the Philbrook is not a straight forward consideration. The villa is a home built like a bunker but used as a museum. The north additions and Kravis Wing are built like a commercial building but used as a museum. While a complete energy efficiency audit of the buildings was not conducted, the following are our observations and recommendations:

A. Villa Wall Insulation – the walls of the villa are constructed of multiple layers of masonry components without an air gap. The thermal camera inspection of the villa walls indicated surprisingly good insulation to heat movement. Due to the construction of the villa walls, no further insulation is practical.
B. Villa Attic Insulation – the attic floor is made of poured concrete. The attic roof joists have no added insulation which would have been typical for the type and date of construction. No outdoor attic ventilation was noted. Fire rated spray foam insulation could be applied to the underside of the roof decking and the attic space converted to a conditioned space. This would decrease the thermal load on the building and the HVAC equipment located in the attic. However, spray foam applied to the roof decking is a recent development and has not been uniformly accepted by building professionals, de Verges included in

this list. We recommend that further evaluation of the attic should occur to determine the best, if any, methods to improve energy efficiency of this area.

C. Villa windows – the villa windows are in very good condition and should not be altered other than the addition of interior storm windows as discussed above. The double hung windows add to the historic characteristic of the building and should not be replaced or altered. Regular painting and caulking will keep these windows in good condition for many years.

D. North addition and Kravis additions were not inspected in detail for this report.

E. Building Doors – the main museum entrance is the revolving door in the Kravis Wing but other original exterior doors are used in the villa to accommodate the 200,000 museum visitors per year. With each opening from one (1) of the traditional exterior doors is a loss of conditioned air and/or the gain of unconditioned air. The villa doors are nearly 100 years old, are not insulated, and were not designed to be air tight **(Photo 11)**. The Kravis Wing revolving door **(Photo 12)** is the most efficient in controlling the movement of conditioned air per visitor; however, this door is in poor condition. The door gasket seal is completely worn out **(Photo 13)** which allows for continuous air leakage from this door. The east exit door in the Kravis Wing is also heavily used and the door sweep gasket is also worn **(Photo 14)** and also allows for constant air leakage. General door use in the museum is likely the largest air leakage source of unconditioned air for the building.

Building Doors Recommendations – We recommend that museum guests should be directed to use the revolving doors in the Kravis Wing. The use of the traditional swing doors in the Kravis Wing should be limited to wheel chair use and those that have trouble using the revolving door. Signs should be installed at the door to explain the energy savings from using the revolving door. Also, the revolving door seals should all be replaced and inspected during the quarterly building preventative maintenance inspection. All other doors should be inspected for air tightness and repaired as necessary, as well as inspected during the quarterly building preventative maintenance inspection.

F. **HVAC Improvements** – The Heating Ventilation and Air Conditioning (HVAC) system of the museum is provided by two (2) aging, traditional gas fired hot water boilers and two (2) cold water chillers that feed a system of forced air handlers' throughout the building. The boilers and chillers are nearing the point of failure and should be replaced with more energy efficient systems. The current boiler/chiller system of water temperature controlled heating and cooling was a typical design for a commercial building. The villa ductwork has been updated into a multizone system that the museum staff has used successfully for many many years. However, since these systems are in need of replacement, a more energy efficient hot and cold water system should be considered, as opposed to replacing the current system with a new boiler/chiller system. Commercial buildings with hot/cold water systems can be served with a chiller that produces both cold water and stores the typically wasted warm air generated from the chiller operation. One chiller can produce hot and cold water which is stored in super insulated tanks. In the summer at night, the cold water tank is allowed to freeze into a block of ice that is then melted during the peak heating hours of the day to cool the building. This type of HVAC system could be used with your existing heat exchanger forced air heating/cooling system. The air handlers' blower motors could be replaced with multispeed motors that will operate more efficiently and allow the HVAC operator to better control temperature and RH in the building.

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Other HVAC Improvements

With the replacement of the HVAC chiller system, we also recommend the following additional changes:

- Improve air filtration in the buildings – currently the air filters located in the air handlers are Minimum Efficiency Reporting Value (MERV) 8 which is commonly used in factories and low end office buildings. During our inspection of the villa air handlers, we noted that some filters were poorly fitted into the filter bank holders and were allowing unfiltered air to pass. We recommend that the air filters be replaced with MERV 11 air filters and the filters be taped in place to minimize air flow bypass. The Higher MERV filters will help minimize particulates in the air that could impact artwork.
- Air Conditioning Condensate Management – condensate generated by the air handlers is collected into pans under the coils as in all air conditioning systems, which flows by gravity or pumped to a drain. <u>During our inspection of the villa air handlers, we noted that the collection pans, condensate pumps, and drains did not have a water monitoring system to warn of condensate overflow.</u> Condensate overflow can occur any time of year in your HVAC system. Condensate pans, transfer condensate pumps, and drains must be cleaned and inspected at least twice per year by museum staff or well regulated outside contractors. <u>Condensate overflow can be catastrophic in a museum and is often undetected until damage to finishes and artwork has already occurred.</u>

- Makeup Airflow Design – in the planning of the new HVAC system, the required make up airflow should be calculated by carbon dioxide levels in the air and outdoor temperature and not calculated by a static or fixed amount. This process will allow for improved temperature control and thermal stability.

- Planning and Design of the New HVAC System – the replacement of a commercial building HVAC system is a large investment for any facility owner and must be planned and excicuted correctly so the museum is not saddled with incorrectly sized and/or inefficient equipment. When a system has been designed and bid, Philbrook should hire an HVAC engineering company, with museum and energy efficient equipment experience, to review all plans and oversee the final installment. This company should not have any financial interest in the equipment purchased and may not bid on installing the system.

- PSO's Power Forward Program – Philbrook staff should investigate our power utility (PSO) Power Forward Program that pays owners to purchase high efficient electric equipment such as HVAC equipment and light bulbs. This utility funded program could save Philbrook a tremendous amount of money during this process.

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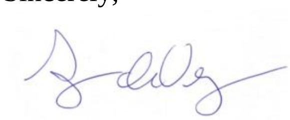
Other Energy Efficiency Options for Philbrook:

- LED Light bulb – Most of the artwork lighting at Philbrook is with incandescent bulbs. All incandescent bulbs in the facility should be replaced with LED bulbs that can be selected to provide the art installer the same light output and color temperature as the current incandescent bulbs provide. LED bulbs use much less energy and generate less heat, which lowers the summer heat load and last much longer. It will also lower operating cost for bulb replacement by staff. LED bulb replacement may be paid for all or in part by PSO's Power Forward Program.

de Verges & Associates would be happy to assist Philbrook with other environmental and sustainability issues that may involve HVAC, lighting, waste minimization, process improvement, procurement, staff training, water quality, landscaping and improved indoor air quality.

Please call 918-748-8098 if you have any questions.

Sincerely,



Guy de Verges
Sr. Environmental Consultant of
de Verges & Associates
Environmental Consulting, Inc.

Photos:

Photo 1

Photo 2

Photo 3

Photo 4

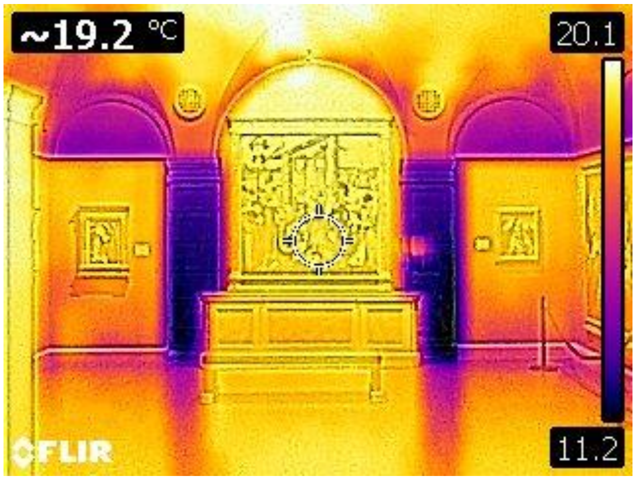


Photo 5

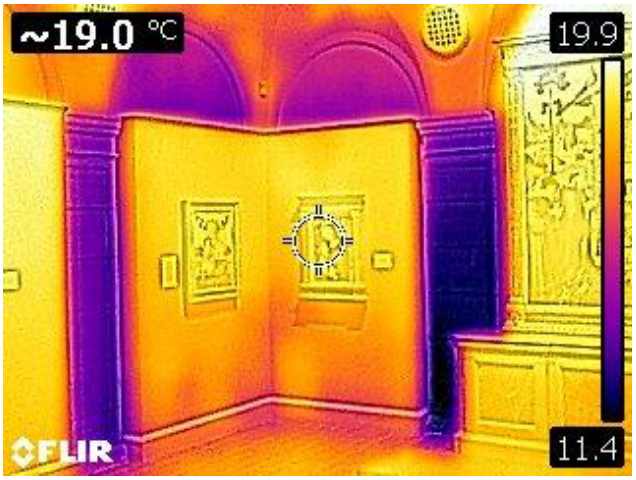


Photo 6

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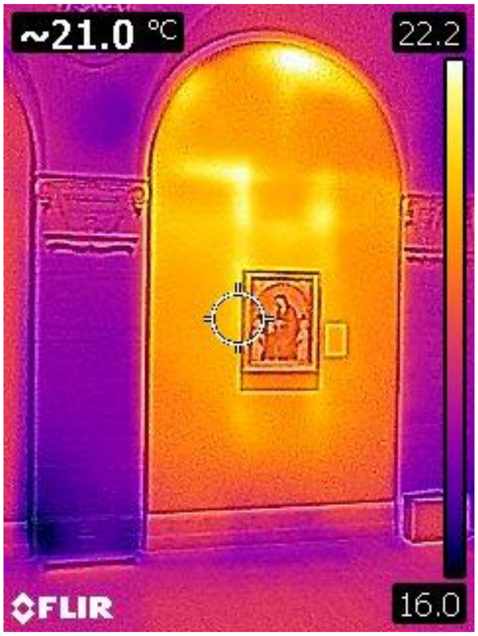

Photo 7

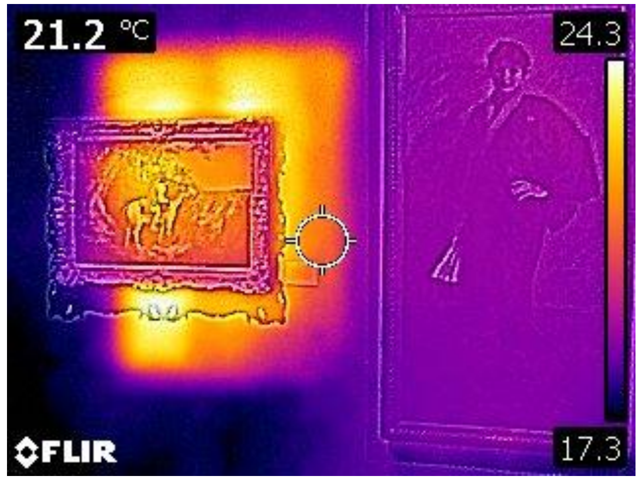

Photo 8

Photo 9

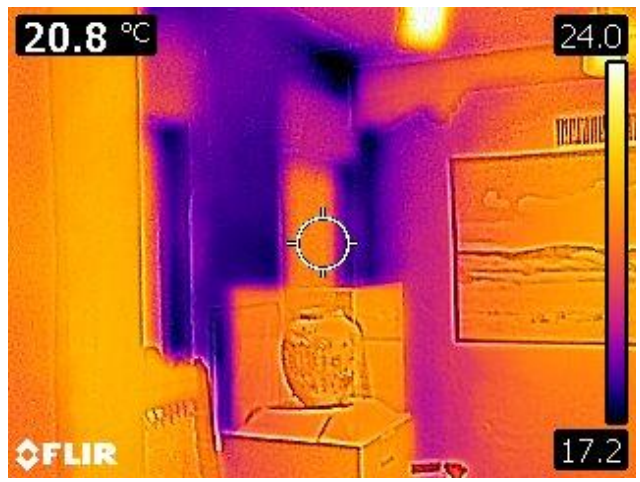

Photo 10

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Photo 11


Photo 12


Photo 13


Photo 14

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Photo Credit: Philbrook Museum of Art

TITLE: Sustaining Collections: Environmental Recommendations for Philbrook Collections

PROJECT: NEH Sustaining Cultural Heritage Collections Grant

CLIENT: Philbrook Museum of Art

DATE: October 2017 – November 2018

CONSULTANT:

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EXECUTIVE SUMMARY:

The Philbrook Museum of Art's efforts under the 2017-2018 NEH Sustaining Cultural Heritage grant exemplify the recent trend away from prescriptive standards towards a philosophy that integrates risk management and collaborative decision making to promote stewardship that is sustainable for the earth, the institution, the building and collection. This project has provided a successful example of how bringing together an open-minded interdisciplinary team can result in a more nuanced understanding of needs and development of appropriate solutions.

Over the course of the project the following concepts were generally agreed upon by the committee:

- The needs of the Philbrook's historic structure must be considered in equal measure to the collections
- Attempts to control the environment in the Kress Gallery have caused damage to the historic structure while not fully succeeding in providing conditions as tight as desired.
- There must be a substantial rethinking of the use of space within the building
- If issues like appropriate setpoint control, seasonal setbacks and short-term shutdowns cannot be considered, then there is little room for sustainability in the design of a future HVAC system.

Key Observations & Recommendations:

- The Temp and RH data comes from the Building Management System (BMS) and may not accurately represent what is being felt by the collection. The Philbrook should purchase additional equipment for monitoring environmental conditions in collections spaces at the museum and off-site storage facility. This will help inform the next round of decisions about collection placement and environmental needs. Additionally, all monitoring equipment should be regularly checked for accuracy.
- Despite the ageing equipment, Philbrook Facility staff have managed to create an environment that over the past year has been generally stable and appropriate for the collection.
- BMS or PEM2s data from various collection spaces show that the mean temperature is between 68-71°F. Using a setpoint of 70°F +/-2°F the spaces that hold the majority of the collections are within that range 75-99% of the time showing that Facilities staff have achieved remarkable control given the foibles of the system. The spaces with the most variation are the Kress galleries. The spaces analyzed have Time Weighted Preservation indices between 33 – 42, which shows the collection is at risk for faster chemical ageing than desired. A TWPI above 45 would move the collections out of a Risk rating into an OK rating. This can be achieved by aiming for lower temperatures. While this may be difficult to achieve in areas where human comfort is a priority, it should be a goal for storage areas (see specific target recommendations below). [1]
- BMS or PEM2 data from various collection spaces show that the mean RH is between 45-54%. In most of the spaces analyzed, the minimum RH was in the high 20s to the low 60s e.g. 27-62%. The spaces with the greatest fluctuation (i.e. minimum of 16% and maximum of 82%) were seen in the Kress Galleries. Overall, using IPI's metrics, most spaces have reasonable %DC and %EMC ratings which result in either an OK or good rating for the possibility of mechanical damage. Generally, the

[1] See Appendix 3a – eCNB Metrics Comparison Report and Appendix 2 - IPI Preservation Metrics

Philbrook Facilities staff have been able to achieve good RH control as measured by the eCNB performance reports.[2]

- While the current HVAC system does not allow for this, RH control should be prioritized above temperature control. Temperature can be allowed to fluctuate if it helps stabilize RH.
- Collection care is a focus for the Philbrook and their exhibition and storage spaces show sound implementation of best practices for preservation. While there is damage or deterioration seen on individual pieces, the collection is in good condition overall. This includes, the Kress Collection which are some of the most sensitive and valuable pieces in the museum.
- Much of the current debate over environmental conditions has focused on exhibition environments with the goal of bringing loan requirements into alignment with actual institutional practice. While there is increasing understanding that strict demands for 50/70 conditions is a misunderstanding of environmental needs, deviating from this may require the Philbrook to justify its practices to some lenders.
- Optimal conditions for collection storage spaces is not necessarily the same as for the galleries.
- While research indicates that many materials and types of artifacts can withstand broader environmental parameters without incurring damage, much more information is needed from the conservation science and preservation community for the field to feel increasingly comfortable with broadened setpoints. Additionally, it must be acknowledged that some collections, due to their materials, construction or condition are fragile and highly responsive to environmental conditions and will therefore justify extra measures for tight control.
- Well designed microclimates with either active or passive controls may be needed for the most sensitive collection items or when artifacts with specific needs are placed in exhibition spaces that aren't optimized for those conditions. This may result in additional expenses for exhibitions and should be taken into account when planning exhibitions and installations.
- The Philbrook should have good digital images and condition reports for a wide range of sensitive materials (i.e. beyond the Kress collection paintings, which have extensive condition documentation). This would allow for better comparison and tracking of any kind of damage by environmental or other causes.

[2] See Appendices 2 and 3a-3e.

PROJECT GOALS:

The NEH Sustaining Cultural Heritage Collections Program of the National Endowment for the Humanities grant received by the Philbrook Museum of Art was designed to "support the integration of sustainable practices into the Museum's strategy for environmental control in the future and identify ways to balance the needs of the historic villa and the needs of the collection, which—as a 2009 historic structure analysis reported—are oftentimes at odds. The current HVAC system is at the end of its life and in dire need of replacement."[3] The interdisciplinary project team was asked to apply the latest research into sustainable approaches to climate control and preventative conservation to evaluate system needs, identify opportunities to maximize sustainable approaches, identify the environmental needs for the historic structure and the collections housed within, and determine how best to achieve both sets of goals in proactively planning for the HVAC system's replacement.

The goal for this report is to propose recommendations for environmental parameters for the Philbrook's varied collection that consider recent research and thinking in the preservation field. Conservators Dianne Modestini and Shan Kuang were responsible for summarizing the needs of the paintings that form the museum's Kress collection. It will be the job of others on the interdisciplinary team to turn these recommendations into engineering solutions that will meet the needs of the building, collections, staff and programming.

One of the original goals of the project as stated on the November 7, 2017 on-site meeting agenda was to address the issues of environmental stability in the Kress Galleries to better meet the needs of the sensitive and valuable panel paintings. During the initial site visit the project team was told that all interventions are "on the table" and the job of the committee was to imagine and sift through the possibilities large and small. This intellectual freedom gave rise to discussions that acknowledged that the needs of the historic building could not be met with current policy. "Based on this conclusion, Philbrook has decided to reimagine the Kress Galleries, bringing their form and function closer to their original design as a series of sunrooms and porches. Uncovering windows will allow natural light to enter the space and provide a visual connection to the surrounding gardens. The biggest concern about changing the space is the need for additional display space for the Kress Collection."[4] The new focus of the report was now outlined as focusing on the big picture of collection care recommendations and sustainability, rather than specific designs of the new system until the work begins on the new Master Plan in 2019.

METHODOLOGY:

This report draws upon information from the information from the November 2017 site visit, information from the three conference calls by the project team, supporting documentation provided by Philbrook staff and the team of consultants engaged on this grant project, review of published and

[3] Grant Narrative
[4] NEH Sustaining Cultural Heritage Grant: HVAC Redesign Meeting #3 (Conference Call) 11/8/2018 notes distributed by R. Keith

unpublished literature, as well as personal communications with colleagues working in relevant areas of conservation treatment and preventive care. Data for the eClimateNotebook reports was obtained from the Philbrook museum building management system and PEM2 dataloggers.

The statements and opinions contained herein are for the use and information of the Philbrook Museum of Art. The opinions reflect the judgments of consultant and conclusions drawn in this report are based on those conditions and surfaces accessible by unaided visual observation during the site visit. No warranties or guarantees can be inferred from, or implied by, the statements or opinions contained in this report.

THE "50/70 DEBATE":

Historical context

Over the last decade museums and preservation professionals have been re-examining assumptions about environmental guidelines for collection preservation. This recent conversation has become known in the field as the "50/70 Debate". Conditions of 50% +/- 5% relative humidity and 70 degrees F +/- 2°F (shortened to 50/70 for convenience) have become de facto standards over the years without regard to the type of collection, institution or resources under discussion. There are several good summaries of the history of the history of environmental management for cultural heritage[5] but a brief description of key points is summarized here.

Documented environmental management of collections in the U.S. dates to the beginning of the 1900s. Unintentional experiments on art storage conditions resulting from hiding art during World War II led to interesting observations about temperature and humidity. But the root the 50/70 recommendation appeared to be codified in the seminal 1978 publication *The Museum Environment* by Gary Thomson. Thomson's assertion that controlling environmental conditions could minimize damage and slow deterioration was well supported and has been thoroughly accepted. However, his discussions of more defined parameters were made for specific climates and objects and were not meant to become a strict guideline, nor have they ever been formulated in a field-specific standard.

The word *standard* has a general definition as "an idea or thing used as a measure, norm, or model in comparative evaluations" but also has a second definition as "something set up and established by authority as a rule for the measure of quantity, weight, extent, value, or quality". In this second definition, standards are generated by many stakeholders to establish uniform criteria, methods, processes and practices. They provide a level of consistency that can be used for a common purpose such as comparison of testing results. Standards can be used to establish minimum levels of

[5] See the AIC Wiki: Environmental Guidelines - http://www.conservation-wiki.com/wiki/Environmental_Guidelines for a summary of this history along with associated downloads, references and links, as well as Stefan Michalski's article "Climate Guidelines for Heritage Collections: How We Got Here, and Where We Are Today" Smithsonian Institution's Summit on the Museum Preservation Environment March 2013 https://repository.si.edu/bitstream/handle/10088/34611/13.03.EnvironPreservationSummit.Final.pdf?sequence=1&isAllowed=y (November 2018)

performance and quality for ensuring compatibility of products and services from different sources or different time periods. Over the past 50 years 50/70 has become a standard by the general definition, but not codified through agreement by any particular organization, e.g. AIC, AAMD, IIC, ASHRAE.

While 50/70 became accepted as a general guideline, many, if not most, institutions had trouble achieving these conditions and there are many ways in which it either does not meet or is directly counter-productive to our needs[6]:

- 50/70 was based as much on human comfort and HVAC technology as collection needs.
- 50/70 should not apply to all objects and collections as there are many types of materials (e.g. metalwork) for which it is not the best environment.
- This recommendation was made without regard to building type and many historic structures in northern climates may be damaged by efforts to humidify or dehumidify.

This last point, directly relevant to the Philbrook, was reinforced in 1992 when the Association for Preservation Technology (APT) and the American Institute for Conservation (AIC) adopted the New Orleans Charter for Joint Preservation of Historic Structures and Artifacts, giving the needs of historic structures on same importance as collections.

Current Thinking:

The Philbrook's current project is reflective of the current re-examination of 50/70 and the search for guidelines that meet a specific institution's needs based on its climate, building and collections. Discussions occurring in the field at all levels from professional societies down to individual institutions recognize many issues highlighted in the Philbrook's grant proposal with the need for:

- Increased sustainability in all institutional operations for both economic and natural resources stewardship reasons
- Environmental policy that reflects current practice and facilitates discussion on loan parameters
- More research on the environmental effects on heritage deterioration

In determining what kind of condition guidelines might be appropriate there have been a number of recent agreements and statements:

- In 2009 the International Group of Organizers of Large-Scale Exhibitions (the Bizot group) broadened their temp and RH guidelines for hygroscopic materials on loan to 40-60%
- At the request of the American Association of Museums Directors (AAMD) the American Institute for Conservation (AIC) formed an Environmental Guidelines Working Group to examine the environmental requirements for museum loans. The statement submitted at the June 2010 AAMD meeting proffered the following principles:
  For the majority of cultural materials, a setpoint in the range of 45-55% RH with an allowable drift of +/-5%, yielding a total annual range of 40% minimum – 60% maximum, and a temperature range of 59-77˚F is acceptable.
    - Fluctuations must be minimized.

[6] Hatchfield, Pam, January-February 2011. "Crack, Warp, Shrink, Flake: a new look at conservation standards" Museum, vol. 90:1, p.42.

  - Some cultural materials require different environmental conditions for their preservation.
  - Loan requirements for all objects must be determined in consultation with conservation professionals.[7]
- Chapter 23 of ASHRAE (American Society of Heating Refrigerating and Air-Conditioning Engineers) Handbook - Heating, Ventilating, and Air-Conditioning Applications has been updated recently to describe the target parameters and performance in terms of climate management.[8]
- The publicly available (for a fee) specification BSI (British Standards Institute) document PAS 198:2012: Specification for Managing Environmental Conditions for Cultural Collections published in 2012 has become a core resource on this topic. PAS 198 focuses on developing a framework for risk-based decision making that allow for a more responsible use of energy.
- The Getty Conservation Institute's Managing Collection Environments Initiative "combines scientific research with fieldwork, investigating the response of hygroscopic materials to climatic fluctuations and the monitoring of objects in situ."[9] The results of this work are not yet available but the project attests to the range of research and interest of major institutions worldwide.

TYPES OF DETERIORATION & THEIR AGENTS:

Mechanisms of Deterioration

Discussions about optimal environments for collections are often too general to be truly useful. A more detailed understanding about the mechanisms of deterioration is therefore needed. For the purposes of this report will use some of the terminology promoted by the Image Permanence Institute (IPI) at the Rochester Institute of Technology (RIT)[10]. More detail on these topics is available from the resources and appendices listed below. Deterioration is broadly broken down into three categories:

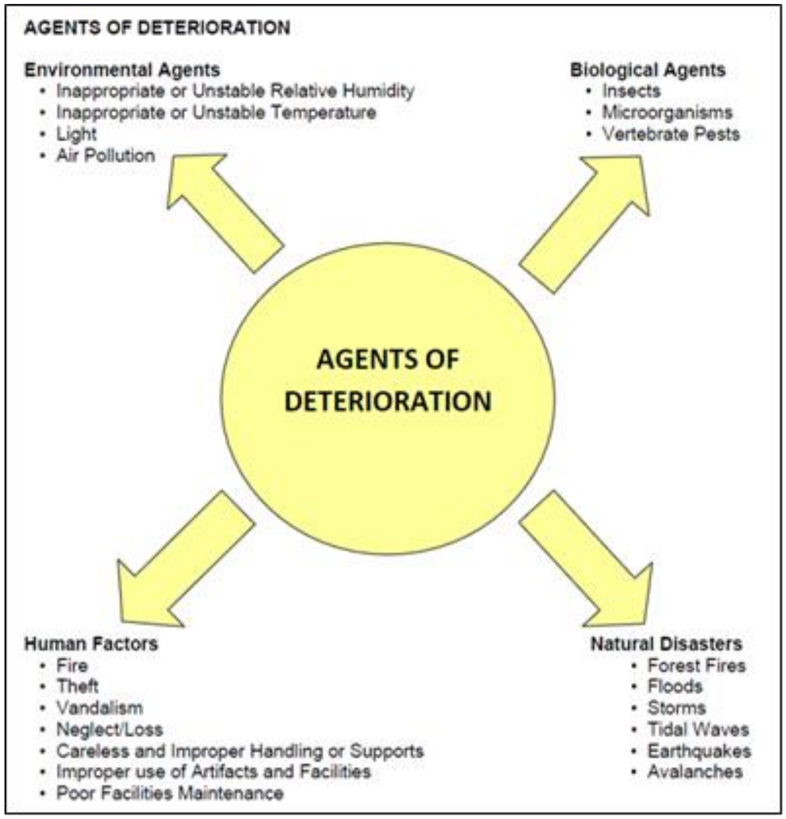
1. **Chemical** – i.e. chemical reactions occurring within the object. This occurs naturally and inevitably as an item ages but can be sped by environmental factors. Examples include change of color in photographs, fading of dyes, degrading plastics or foams, weakened textile fibers, yellowed and embrittled books and paper. Corrosion of metal artifacts is also a type of chemical decay. Generally, this type of change is gradual and therefore often difficult to see until the reaction is advanced.
2. **Mechanical** – i.e. physical damage such as cracking, warping, delamination, slumping. This can be rare and catastrophic, like dropping an artifact, or it can be slow and inevitable like expansion and contraction caused by fluctuating relative humidity.
3. **Biological** – i.e. mold/fungi or insects and vertebrate pests. These biological factors that act on art can be heavily influenced by the environment. Mold growth requires periods of sustained

[7] AIC wiki: Environmental Guidelines http://www.conservation-wiki.com/wiki/Environmental_Guidelines (November 2018)
[8] See Appendix 6 of this report
[9] GCI Managing Collection Environments Initiative Webpage - http://www.getty.edu/conservation/our_projects/education/managing/index.html (November 2018)
[10] Grateful thanks to IPI's Alice Carver Kubick for sharing her research and information

high humidity and humidity. Elevated temperatures will speed insect reproduction cycles and some insect pests are known indicators of high humidity as they feed on mold and fungi.

Agents of Deterioration

"Agents of Deterioration" is a term used by preservation professionals to describe ten primary threats to cultural heritage. "Controlling the agents of deterioration can be done at three levels, through building features, portable fittings, and procedures….Control measures are further divided into five stages -- Avoid, Block, Detect, Respond, and Recover/Treat -- listed in decreasing order of preference. For instance, if an agent is successfully avoided, it will not have to be blocked, detected, responded to, or recovered from. If, however, an agent of deterioration cannot be avoided or blocked, then the other stages must come into play. The first four stages constitute preventive conservation. The last stage of recovery or treatment involves repair, conservation, and restoration of the affected artifact." [11]



Other environmental factors such as pollutants and light can also factor into the decay mechanisms described above. While the focus of this report is on temperature and relative humidity, with Philbrook's conclusion that they may return areas of the present Kress Galleries to their original uses, light will also be discussed. The Canadian Conservation Institute has published an extensive guide to the agents of deterioration and pertinent sections are summarized here[12].

Understanding Temperature

Incorrect temperatures – There are three ways in which temperature can be inappropriate for certain types of collections.

- ***Temperatures too high*** - While humidity and the presence of pollutants are factors in chemical ageing, the prime driver is temperature. High temperature speeds reactions, breaks chemical bonds,

[11] CCI website (December, 2012) http://www.cci-icc.gc.ca/caringfor-prendresoindes/collections-eng.aspx
[12] Canadian Conservation Institute's website https://www.canada.ca/en/conservation-institute/services/agents-deterioration.html

and increases energy in reactions. The rate of decay doubles every 5°C/9°F[13]. Normal room temperature of 68-70°F, comfortable for humans, is too high for the long-term preservation for sensitive collections, predominantly photographic, library, modern A/V and media collections, paper and textiles. While standard human comfort temperatures might be imperative for gallery spaces, whenever possible, areas for long-term storage of collections should be kept cooler if possible. CCI created a table indicating levels of sensitivity for many materials (see table)

- ***Temperatures too low*** – Temperatures below 5°C/~41°F can cause some modern materials to become brittle. While this isn't damaging in and of itself, materials such as acrylic painted surfaces become more vulnerable to mechanical damage if improperly handled. Oil paints and other modern polymers are vulnerable at much lower temperatures i.e. -30°C/-22°F and -40°C/-40°F.
- ***Fluctuating temperatures*** – Recent research by IPI confirms that changes in temperature are quickly felt by collections within 6-12 hours[14], even when they are housed in boxes or cabinets. The greater the exposed surface area, the faster the equilibration. However, CCI's research and that by T. Padfield demonstrate that concern and attention to large swings in temperature (up to 50°C) as well as repeated fluctuations in temperature "has been out of all proportion to its significance for collection preservation."[15]

Table 1a: Chemical sensitivity of materials to room temperature

Low sensitivity	Medium sensitivity	High sensitivity	Very high sensitivity
Wood, glue, linen, cotton, leather, rag paper, parchment, oil paint, egg tempera, watercolour media, and gesso. Serviceable examples of all these exist that are 1–3 millennia old from dry burial or dry enclosures at ~20°C. These examples were protected from any acid exposure, such as air pollution in the Industrial Revolution, and have never been damp. Skin, bone, and ivory of the wooly mammoth have survived intact for over 40 millennia while frozen.	Current best estimate for stable photographic materials to remain usable as images with little or no change, e.g. 19th century black-and-white negatives on glass, 20th century black-and-white negatives on polyester film.	Acidic paper and some film become brittle and brown, difficult to access, e.g. newsprint and low-quality books, papers, post-1850 . Acetate film shrinks, image layer cracks. Celluloid and many early plastics, become yellow, crack, distort. Natural materials acidified by pollution (textiles, leather) weaken, may disintegrate.	So-called "unstable" materials. Typical magnetic media begins to be unplayable, e.g. tapes of video, audio, data; floppy discs. Least stable of the photographic materials decay, e.g. colour prints fade (in the dark), poorly processed items yellow, disintegrate; cellulose nitrate yellows, disintegrates, faster when packaged in large amounts. Many elastic polymers, from rubber to polyurethane foams, become brittle, or sticky, or disintegrate. Some acrylic paints on some canvas supports yellow rapidly.

[13] Kubick, personal communication 9/2017.
[14] IPI's *Guide to Sustainable Preservation Practices for Managing Storage Environments*, Version 2.0 – July 2012 (p. 14) Copy available in Project Fileshare
[15] Stefan Michalski's article "Agent of Deterioration: Incorrect Temperature", Canadian Conservation Institute's website https://www.canada.ca/en/conservation-institute/services/agents-deterioration/temperature.html

Understanding Relative Humidity (RH)

Incorrect relative humidity – Relative humidity (RH) is a major factor into all three forms of deterioration. As with temperature, RH can be too low, too high or too variable. There is an additional category that must be considered – RH above or below a critical value for a particular object. While engineers may use absolute humidity, vapor pressure or dewpoint, for collections RH is the measurement of importance. Organic materials are hygroscopic – they absorb and release water depending on the RH of the surrounding air. This process will continue until the interior moisture content of artifacts reaches equilibrium with their environment. IPI's research has demonstrated that moisture equilibration (in contrast to thermal equilibration) is relatively slow. Depending on the nature of the material, size and surface area, it may be days or weeks until an artifact equilibrates to a change in RH. Placing artifacts into enclosures such as boxes or cabinets will slow this process even further.[16]

- ***RH too high*** – High relative humidity is responsible for corrosion of metals, mold growth and mechanical damage of hygroscopic organic artifacts. High RH is generally considered 65% and above. Mold germinates at 70% and above so all responsible guidelines for upper RH limits top out at 60%. IPI recommends an upper limit of 55% RH as much of the focus of their research is library and archive material and deterioration by processes such as acid hydrolysis is reduced with the lowering of RH.[17] Shell, which may be found within the Philbrook's archaeological and ethnographic collections can be vulnerable to Byne's "disease" which is also a form of acid attack which requires moisture.
- ***RH too low*** – Organic materials will lose moisture to the ambient environment if RH is too low. Generally, 30% is considered the lower limit. Below that, artifacts may shrink becoming desiccated and embrittled. Low RH is, however, optimal for most metalwork.
- ***Fluctuations in RH*** – This has been, for many institutions, the most problematic issue in environmental control. When RH fluctuates, the moisture content of the artifact will fluctuate as the piece reaches towards equilibrium with its environment. This results in expansion and contraction. For artifacts made of multiple materials that will react differently to changes in RH, or artifacts that are constrained or under tension, the differing rates of equilibrium can cause cracking, splits and other forms of damage.
- ***RH above or below an object specific critical value*** – There are some types of artifacts that have specific environmental needs based on their materials, composition or condition. Specific examples of these relevant for the Philbrook collections will be given below.

A reformatted version of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)'s classification criteria for collections environments found in Table 3 of Chapter 23, Museums, Galleries, Archives and Libraries, of the 2015 ASHRAE Applications Handbook is given here for reference.[18] The ASHRAE 2007 table "Temperature and relative humidity specifications for mechanical

[16] IPI, 2012, p.14.
[17] CCI website https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html#tft2a (November 2018)
[18] Courtesy M. Henry 2017

control systems in museum buildings, showing their risks and benefits to various collections" by Stefan Michalski of the Canadian Conservation Institute is given in Appendix 6 of this report but even more recent versions of this table are currently being re-evaluated.

ASHRAE *Applications Handbook* Chapter 23- Museums. Galleries, Archives and Libraries Control Class Criteria[3]		AA	A Float RH	A Fixed RH	B	C	D
Relative Humidity %	Average[1]	50	50	50	50	50	50
	Max (annual)[2]	55	65	60	70	75	75
	Min (annual)[2]	45	35	40	30	25	No Limit
	Max Seasonal Set Point Shift	None	↑10 ↓10	None	↑10 ↓10	No Limit	No Limit
	"Short Fluctuations" Max 24 hr range	±5 ≤10	±5 ≤10	±10 ≤20	±10 ≤20	No Limit	No Limit
Dry Bulb Temp °F	Average[1]	70	70	70	70	70	70
	Max (annual)[2]	83	83	83	86	86	No Limit
	Min (annual)[2]	57	48	48	48	No Limit	No Limit
	Max Seasonal Set Point Shift	↑9 ↓9	↑9 ↓18	↑9 ↓18	↑18 ↓18	No Limit	No Limit
	"Short Fluctuations" Max 24 hr range	±4 (≤8)	±4 (≤8)	±4 (≤8)	±9 (≤18)	No Limit	No Limit

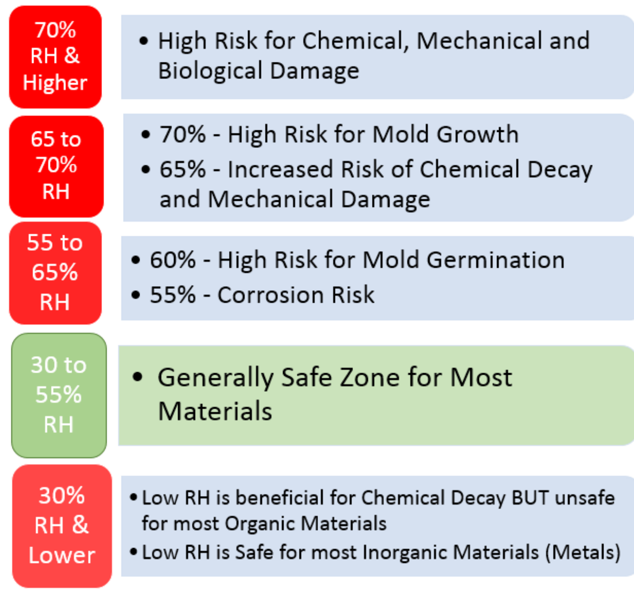
Notes:

1. Average conditions are generally accepted as 70°F, 50%RH for loans, or the historical average for the permanent collection;
2. For example, an annual set point range within 45-55% RH, with 5% allowable drift from the set point value, would give a total annual range of 40-60%; this is Class A, Fixed RH;
3. Class of Control A is better than Class of control B, B is better than C, *et cetera*.
4. Average conditions are generally accepted as 70°F, 50%RH for loans, or the historical average for the permanent collection;
5. For example, an annual set point range within 45-55% RH, with 5% allowable drift from the set point value, would give a total annual range of 40-60%; this is Class A, Fixed RH;
6. Class of Control A is better than Class of control B, B is better than C, *et cetera*.

The American Institute for Conservation (AIC)'s Environmental Guidelines Working Group recommendations presented to the American Association of Museum Directors (AAMD) in June 2010 build on the research of CCI and other professionals working on this topic at the Getty Conservation

Institute, IPI, etc. "For the majority of cultural materials, a set point in the range of 45-55% relative humidity with an allowable drift of +/-5%, yielding a total annual range of 40% minimum to 60% maximum… is acceptable"[19]

They are proponents of sustainable strategies
HVAC Shutdowns over nights and weekends
Adjusting set points nights and weekends
Adjusting seasonal set points to be cooler and drier in the winter, warmer and more humid in the summer while staying within safe limits defined by them in the table on the right.



IPI's recommendations are slightly different with a safe zone that is lower in RH (i.e. 30-55%) than that proposed by CCI and accepted by AIC. This is the result of their focus on library/archive material including paper and photographs that are highly sensitive to hydrolysis. Their overall description of RH recommendations is summarized in the table shown here. This demonstrates that even with broader standards, careful attention must be paid to the types of materials and collections.

Understanding How Materials Behave

Much of the discomfort in loosening environmental control is due to the lack of good understanding on how specific materials and collection items behave. There is broad agreement in the conservation field that more research is needed in this area. Studies examining the affect of environment on modern materials may or may not be directly relevant to historic and ancient artifacts. Furthermore, it is recognized that past conservation interventions will also change the way an artifact responds to its environment.

Currently laboratory research is underway at the Getty Conservation Institute on "the mechanical characterization of materials together with in-situ testing to more precisely identify the conditions under which irreversible damage occurs in cultural heritage materials as a result of climatic agents of deterioration. Better understanding of these conditions can help collections care professionals determine whether permanent damage occurs in susceptible materials exposed to the broader acceptable climatic ranges currently under consideration by the conservation field and to understand the rate and degree of fluctuation these materials can withstand."[20]

[19] AIC wiki: Environmental Guidelines http://www.conservation-wiki.com/wiki/Environmental_Guidelines (November 2018)
[20] GCI Mechanical Characterization of Materials Webpage - http://www.getty.edu/conservation/our_projects/education/mechanical/

In his talk "Climate Guidelines for Heritage Collections: How We Got Here, and Where We Are Today" Stefan Michalski, Senior Conservation Scientist, Canadian Conservation Institute summarized his own earlier research published in 1993 that "demonstrated that the "hockey stick" stress curve applied to a variety of materials, not just stretched canvas. However, he also noted that if one looks at risk-of-fracture (cracking) rather than material stress itself, the smooth "hockey stick" curve is replaced by a "bathtub" curve that shows negligible risk of damage over a wide RH range, coupled with sudden and dramatic increases when certain thresholds for unusually high or low RH are crossed. This is a better representation of the actual loss of value to collections than looking at stress, which in most cases does not translate into detectable damage.[21]

Michalski also made the important observation that the ability of older objects to withstand RH fluctuations in the present is predicated on the range of fluctuations to which it has been exposed in the past. There are a couple of different models for predicting damage. The first is "single cycle stress" which he describes as "repetitive stresses can give rise to fatigue cracking….engineering data from many materials shows that at about one quarter of this stress for brittle materials (glass, ceramics, old oil paint) and one half of this stress for tough materials (wood, paper, leather) fatigue cracking will occur after about a million cycles. By about one eighth of this stress, fluctuations will be tolerated indefinitely, but since it will take 3,000 years to reach a million daily cycles (!), and since most objects cannot respond fully to cycles faster than this, then we can take the million cycle /one quarter stress combination as a very cautious extrapolation of how much to worry about multiple fluctuations."[22]

The second model that describes the ability of artifacts to withstand damage is the concept of "proofed" fluctuation i.e. the largest fluctuation experienced by the object. Any fluctuation smaller than the proofed will cause little or much less new damage than previously sustained. So, for example, an object that has experienced conditions that fluctuate ±20% RH, so unless they have been repaired, their proofed fluctuation is typically at least ±20% RH. These are cautious estimates based on observations of collections, and currently available mechanical models.[23]

IPI's recent and ongoing research with libraries and archives has investigated effects of seasonal setbacks and temporary nightly or weekend HVAC system shutdowns on collections with the goal of promoting more economically and environmentally sustainable recommendations for HVAC systems. Their research indicates that because thermal equilibrium takes time, short-term deviations from optimal conditions are generally not even felt by collections. That it is the longer, seasonal deviations from optimal conditions that lead to damage over time and should be addressed. Additionally, their

[21] Smithsonian Institution's Summit on the Museum Preservation Environment March 2013 https://repository.si.edu/bitstream/handle/10088/34611/13.03.EnvironPreservationSummit.Final.pdf?sequence=1&isAllowed=y (November 2018)
[22] CCI Website - https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html#tft2a
[23] CCI Website - https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html#tft2a

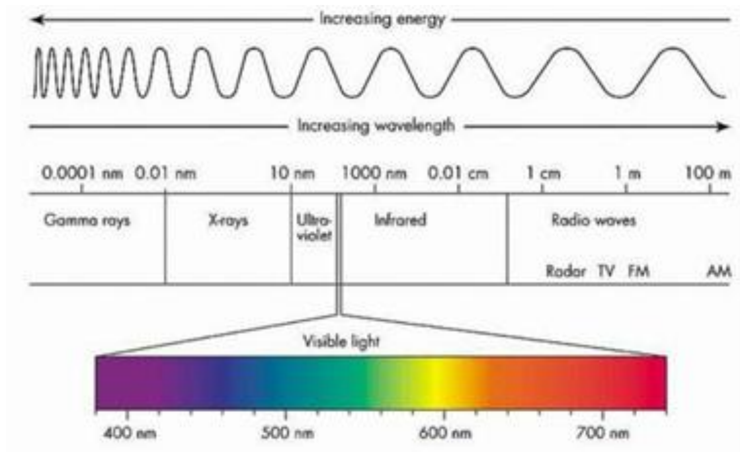
research shows that good enclosures e.g. cabinets and boxes, have a noticeable effect in buffering collections from environmental swings.[24]

Understanding Light

General

Light (sometimes also referred to in the professional literature as radiation) is best thought of as a spectrum consisting of ultraviolet light (UV) at the short end, visible light and infrared at the long end.

UV Light



UV light is measured in microwatts of UV radiation per lumen of visible light (µW/l). The high energy of UV radiation particularly damaging to artifacts. UV light is not visible to the human eye and therefore removing it from museum lighting causes no change in appearance. Daylight is generally the strongest source of UV light. Fluorescent, metal halide and mercury vapor lights also emit UV radiation. UV light can be measured using a UV meter. During the site survey an Elsec 764 UV meter was used to take UV light measurements. Ideally UV light should be as close to zero as possible and light sources emitting UV measurements above 75 µW/l should be reduced.

Visible Light

Visible Light is, of course, necessary in museum environments. The standards that have evolved in the preservation community recognize that levels of light must be high enough to adequately view artifacts on display but anything more than that causes unnecessary damage and should be limited. Visible light levels are measured in lux (lumens per square meter) or footcandles (FC). One footcandle is slightly more than 10 lux. Light levels can be measured using a light meter.

Infrared Light

Infrared (IR) radiation, when absorbed, causes a rise in temperature. IR light is also beyond the detection of the human eye. The effects of heat on collections are covered more specifically in the section on incorrect temperatures but it is important to recognize that light radiation acts as a catalyst in the oxidation of materials – particularly organic artifacts.

Light Damage

Light damage, which is cumulative and, once sustained, irreversible, is a function of light intensity (in lux or footcandles) times length of exposure. Lights that may be set at low levels but are on 24 hours a day will cause the same amount of damage as higher light levels do in a shorter period of time. For example, artifacts exhibited with 50 lux of light which is kept on for 24 hours will receive the same amount of light

[24] IPI's *Guide to Sustainable Preservation Practices for Managing Storage Environments*, Version 2.0 – July 2012 (p. 14) Copy available in Project Fileshare pp.14-15

damage (50 x 24 = 1200) as artifacts exhibited at 200 lux where the light is on for only 6 hours when the exhibition is open to the public (200 x 6 = 1200). Reducing the effect of light damage can therefore be done by lowering overall lighting levels as well as reducing the amount of time that exhibits are lit.

The most commonly considered type of light damage is fading of dyes or pigments but light damage also manifests in other visible forms such as changes in colored pigments or bleaching of wood artifacts (and in some cases darkening of some types of varnished wood). In addition, there are unseen chemical changes such as cross-linking of varnishes, and the physical breakdown or embrittlement of organic materials such as cellulose fibers.

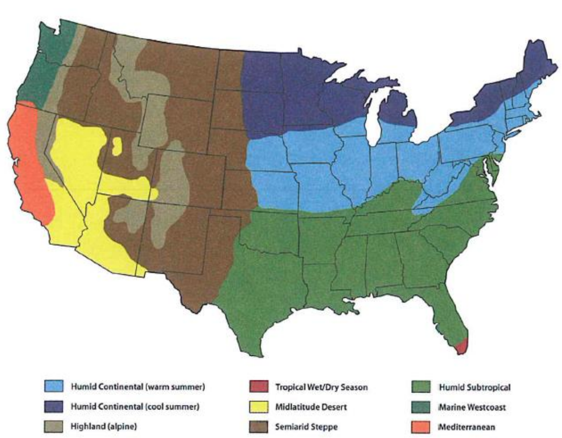
Controlling Light and UV Exposure

Different types, sources and levels of light will be necessary in different parts of a museum or historic home environment. For example, storage environments require light levels high enough for curatorial work to be conducted, but there is no need for daylight and lights should be off when not in use. In other areas daylight might create a desired effect (e.g. historical accuracy in a historic room) but steps should be taken to minimize its damaging effects and, in those particular spaces, objects less susceptible to light damage should be chosen for exhibition.

Lighting may be divided into two general categories: ambient lighting of the overall space and task lighting of the artifacts. Again, different types of light fixtures or, if necessary, a mixture of daylight and artificial light may be combined.

- Methods for reducing total light exposure include:
  - Window shades, films and filters
  - Decreasing the number of light fixtures
  - Decreasing the wattage of bulbs
  - Using light dimmers, viewer activated switches or motion sensors
  - Rotation of artifacts on and off exhibit
- Methods for eliminating UV light include:
  - Eliminating daylight.
  - Using UV absorbing plastic on windows.
  - Applying UV absorbent varnishes to window glass.
  - Using low UV output light fixtures like LEDs.
  - Using UV filtering shields and sleeves (available as thin plastic sleeves or hard plastic tubes) for fluorescent fixtures.

There is a dearth of research on exactly how long most UV filtering plastics, films and varnishes will maintain their efficacy but information from suppliers suggest anywhere from 5-15 years. Research done by the Canadian Conservation Institute (CCI) suggests that 10 years should be considered a general lifespan for UV filtering plastics and films.



ENVIRONMENTAL CONDITIONS:

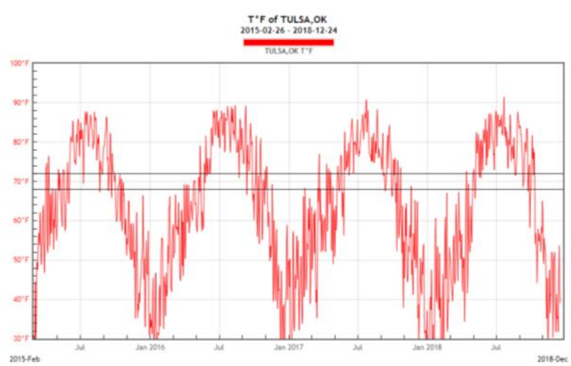
Local Conditions

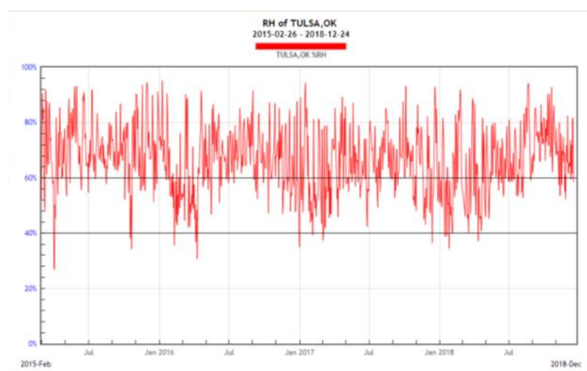
Understanding Tulsa's exterior environment is essential in determining how well the museum's building buffers the environmental and how much work the HVAC system will require to change the internal environment. The Philbrook is located in Tulsa, Oklahoma in the Northeast corner of the states. Tulsa climate ranges from humid subtropical to temperate and is classified as Climate Zone Number 3, Subtype A by ASHRAE.

Tulsa summers hot and humid while winters are shorter and less severe than those of the more northern Plains states. Periods of extreme cold are infrequent, and those lasting more than a few days are rare. The National Weather Service's website states that "the climate is essentially continental characterized by rapid changes in temperature."[25] The last three years of climate data from the Tulsa airport were downloaded into IPI's eClimateNotebook software. The median temperature over the past three years is 64°F, and temperatures throughout the year fluctuate from 2°F to more than 100°F. RH too varies widely throughout the year from 8% RH up to 100% with a median of 67%. Subtropical climates are prone to relative humidity conditions that may promote mold/mildew and biological decay. Precipitation is average, but the city is prone to major flooding as well as hail, strong winds and tornadoes.

TULSA,OK

Date Range		Temperature		Relative Humidity		Dew Point		T Limits		RH Limits	
Start	2015-02-25	T°F Mean	62.4	%RH Mean	66	DP°F Mean	49.6	T°F <68	54.1%	%RH <40	11.6%
End	2018-12-23	T°F Median	64.9	%RH Median	67	DP°F Median	52.1	T°F [68,72]	10.4%	%RH [40,60]	27.7%
		T°F Min	1.9	%RH Min	8	DP°F Min	-5.8	T°F >72	35.5%	%RH >60	60.7%
		T°F Max	104	%RH Max	100	DP°F Max	80.9				
		T°F Stdev	19	%RH Stdev	20	DP°F Stdev	18.6				





Tulsa temperature 02/2015 – 12/2018 *Tulsa RH 02/2015 – 12/2018*

The black bands in the middle of each graph indicate the range generally considered safe for collections showing how far removed the exterior conditions are from desired.

Environmental Monitoring at the Philbrook

Environmental monitoring at the Philbrook has relied primarily on data obtained from the building management system (BMS)'s sensors. It appears there is a good working relationship between Facilities and Collection staff which facilitates sharing of data. However, BMS sensors are designed to give the

[25] https://www.weather.gov/tsa/climo_tulcliover

Facility staff and engineers data on the system performance. The placement of sensors in ducts or walls may or may not provide accurate information on the environment that the collections are "feeling". Additionally, the format for data export with separate MS Excel files for temperature and RH make it difficult to analyze the data. Five second generation Preservation Environment Monitors (PEM2) from IPI are in use at the Philbrook.[26] The PEM2s accuracy, long-battery life and LCD make it a good choice for monitoring general environmental trends at the Philbrook. However, there are simply not enough monitors in use to provide data to all the relevant spaces in the most efficient manner.

It is strongly recommended that the Philbrook invest in additional monitoring equipment to provide a more thorough understanding of room conditions felt by the collections. This is necessary for exhibition and storage spaces. Specific recommendations on equipment are outside the scope of this report but this consultant will be happy to discuss this further with Philbrook staff upon completion of the current project. This recommendation was also made in the 2002 Conservation Assessment Program (CAP) report by Collection Assessor David Rasch and Architect Rick Wright.[27]

Interestingly the report documented several findings that still hold true in 2018. The following is an excerpt from the report's section on Climate Control and Environment which documented that "Temperature and humidity has been monitored and recorded for some years by the Building Engineer using 13 recording hygrothermographs. These instruments are placed throughout the facility as follows: 1 in permanent storage; 1 in the temporary exhibition space on the main floor of the new wing; 1 in library storage on the lower level of the new wing; 2 in galleries on the lower level of the Villa; 4 in galleries on the main level of the Villa; and 4 in galleries on the upper level of the Villa. The accuracy of the recording hygrothermographs is checked with a hand-held digital hygrothermometer, although the frequency of checks and calibrations is unrecorded.

The hygrothermograph records are reviewed and stored by the Building Engineer who is responsible for climate control within the building. In general, when problems with climate control occur, they are reported to curatorial staff members. However, the Building Engineer should ensure that the most up-to-date knowledge is used to identify potentially damaging situations and/or setup a chain of review of the records to include a preservation specialist such as a Collections Manager or a Conservator.

Examination of some of the hygrothermograph charts reveals relatively stable interior climate throughout the facility. Infrequent spikes in the charts are due to temporary electrical outages caused by storms. Apparently, the backup systems are slow to react to these situations and resultant changes in climate are outside of recommended safe conditions. This may increase the risk of damage to sensitive artifacts. Efforts should be made to set up safeguards that can bring the mechanical systems back online quicker after an outage; thus reducing the potential effects of these spikes.

[26] N.B. The Facility Report shared with the project team lists six dataloggers in use but data was only provided for five.

[27] 2002 CAP report provided by Philbrook staff

Minimal periodic fluctuations in interior climate reveals that not all areas remain strictly and similarly within the desired settings. This may be due to the location of sensors in the mechanical systems, differences in the various airhandling units, differences in ductwork lengths, airflow through the ductwork, and room orientation to compass directions and sun exposure.

In order to more fully understand interior climates in all rooms, needed for building-wide i11telligence, hygrothem1ographs should be used to monitor each individual space that holds

artifacts. As an example of methods to accomplish building-wide intelligence, a group of instruments could be placed in each of the storage areas for one full year of recording to detem1ine any differences among them. Meanwhile, a core group of instruments should be retained in areas that are serviced by different mechanical systems or are on separate floors of the Museum. Continuation of monitoring is recommended in order to more fully understand interior climates. After prolonged monitoring, zones of relative stability may be identified where especially fragile materials may be kept and areas of problematic conditions can be addressed." (p. 10-11)

In addition to installing a more comprehensive environmental monitoring system independent of the BMS, a program of regular calibration checks should be implemented for all monitoring equipment in use in the museum. Additional information on how this can be accomplished can be given to Philbrook staff if desired.

Interior Conditions at the Philbrook Museum of Art

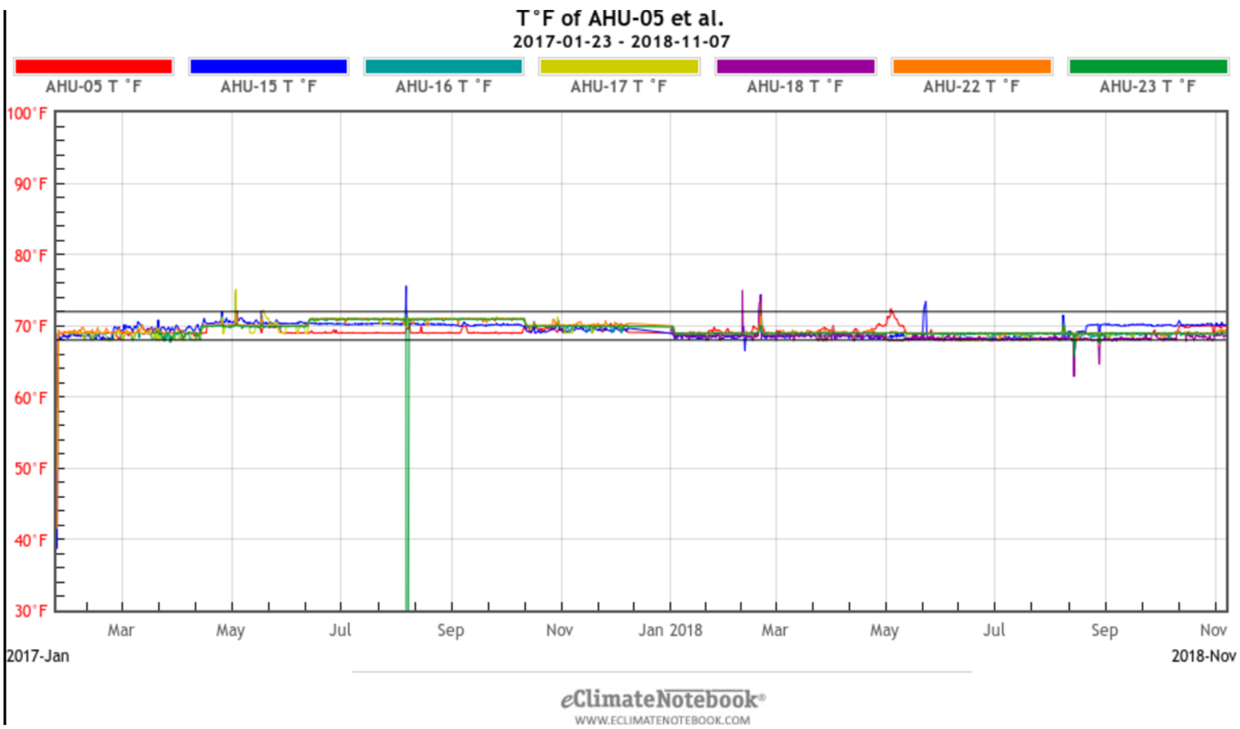
BMS data provided by Philbrook staff was reformatted and imported into IPI's eClimateNotebook (ecNB) cloud-based software program. eCNB provides a number of metrics that are useful ways to analyze environmental data for long-term preservation. A full explanation of the various metrics is given in Appendix 2 of this report. Appendices 3a-3e are a number of reports generated from the eCNB software.

- Appendix 3a gives a summary of the metric data across the various spaces
- Appendix 3b provides an easy comparison of the environmental statistics for each space
- Appendix 3c is a one-page "overview" report that contains graphs, metrics and statistics for each space
- Appendix 3d is a one-page "performance" report for each space that presents the data in a slightly different format than given in 3c. This report filters the data through the desired setpoint range and graphs the performance of the system in meeting those requirements. 3d shows how the system performed under an accepted range of 40-60% RH
- Appendix 3e is the same as 3d but with the accepted range of 45-55% RH

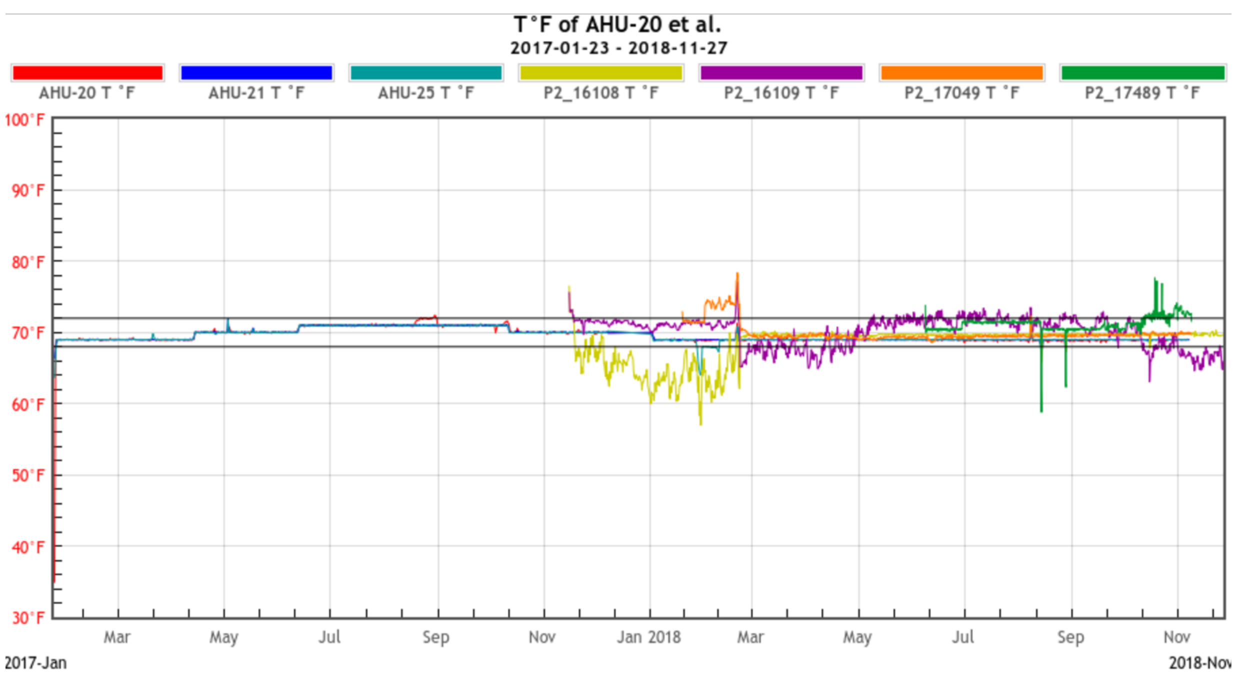
Using IPI's metrics, the data from the previous year shows that the environmental conditions at the Philbrook are generally acceptable. It is clear that the Facilities staff expertise in coaxing maximum performance out of the ageing HVAC system has shown results.

Temperatures fall within a fairly narrow band with minor deviations from standard conditions. eCNB assigns a red "risk" rating in the category of Natural Aging in recognition that the temperature at the

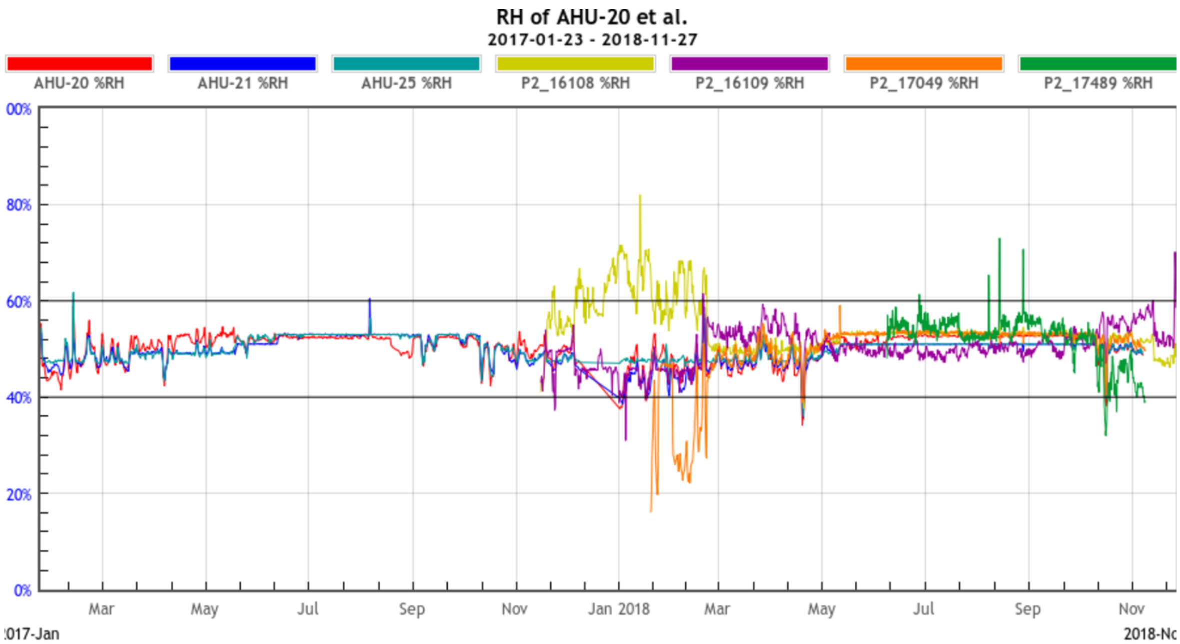
Philbrook is generally around 68-71°F which is warmer than optimal for most collections. When and where possible, maintaining cooler conditions would help reduce chemical aging for the Philbrook collections.



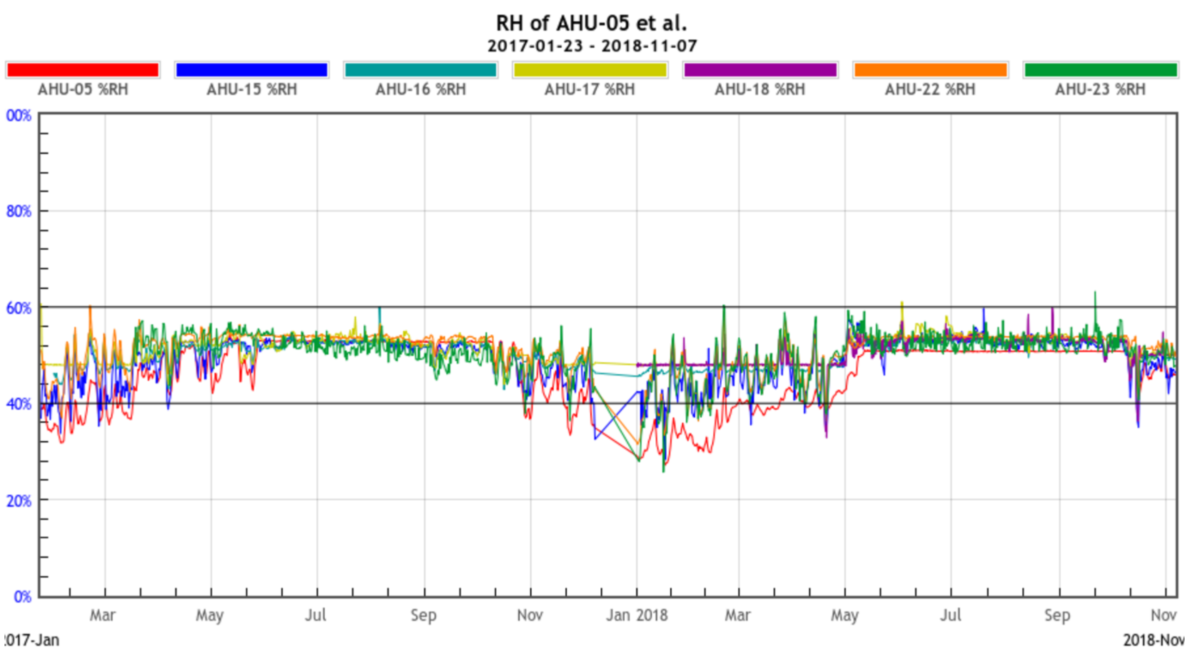
Temperature readings for several spaces on the Lower and Upper floors. Note that the temperature generally falls within the horizontal black bands representing 68-72 degrees F.



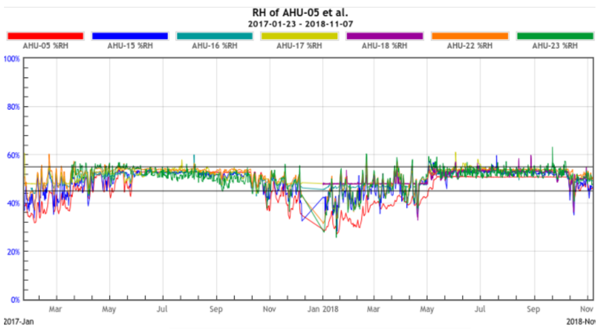
Temperature readings for several spaces on the main floor. Note that the Kress gallery spaces are more variable than other galleries and more frequently exceed the range of the black bands representing 68-72 degrees F.

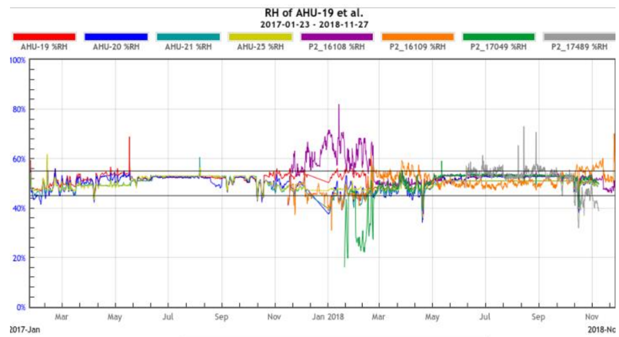


Relative humidity readings for several spaces on the main floor. The Kress gallery spaces are more variable than other galleries and the PEM2 data shows greater variability than the BMS sensor data. The PEM2 data is presumably more akin to what the collections "feel". In this graph the desired RH range is shown as 40-60%.



RH readings for several galleries on the upper and lower floors. For the most part the RH is within an acceptable range of 40-60% RH. The period of greatest concern is November to April when the RH in some spaces shows a sustained drop below 40%. But generally this low RH doesn't drop too much below 30% and so could still be considered safe for some materials. *N.B. the strange appearance of the data trends around December 2017 represents a period of missing data.*





The same data as listed above but with the desired RH range shown as 45-55% i.e. a tighter band than shown in the graphs above, giving a quick visual representation of the late fall/winter/early spring period that is the most problematic environmentally.

PHILBROOK COLLECTION:

Collection Overview

The Philbrook collections include approximately 14,000 works from across the globe and ranging in date from antiquity to the present, making it the most comprehensive in Oklahoma. The collection includes:

- European art and Antiquities - Approximately 1,500 objects, the core of this collection was donated by the Kress Foundation in one of their largest gifts. Artworks such as Tanzio da Varallo's *John the Baptist in the Wilderness*—one of only a small number of works by the artist in American museums—and Biagio d'Antonio's *Adoration of the Child with Saints and Donors*—the largest work by the artist in the United States—help to make Philbrook's holdings of Italian Renaissance art of the fifteenth and sixteenth centuries especially rich. The development of Western art is supported by antiquities including Egyptian, Etruscan, Greek, and Roman artworks.
- American art – numbering nearly 6,500 works, these holdings include eighteenth- to twenty-first-century art, early colonial portraiture and romantic landscape painting, American Impressionism, and Regionalism. In addition to paintings and drawings, the collection also includes three-dimensional objects and approx. 4,000 photographs.
- Native American art, has been one of the oldest collecting areas for the Museum, and it is now one of the Museum's largest holdings with approximately 4,000 objects including iconic works by influential artists from across Indian Country, with particular strengths in basketry, pottery, paintings, and jewelry. The Philbrook's Native American collection is well documented in the institution's extensive archives making the collection particularly significant for research.
- African art (approximately 350 objects)—primarily wood sculpture from over 120 cultural and ethnic groups in Central and Western Africa

- Asian art (approximately 1,000 objects)—which includes a particularly strong collection of Japanese paintings from the Edo Period (1615-1868).
- The breadth of Philbrook's permanent collection is instrumental in fulfilling the museum's mission and serving its community by presenting diverse holdings from cultures worldwide.

Collection Condition

Prior to the October 2017 site visit Philbrook staff shared a list of 11 artifacts that exemplified different aspects of the collection (Appendix 5). This selection of representative artifacts should be used to consider new environmental recommendations for the museum.

A close and thorough inspection of individual artifacts was not possible during the November 2017 site visit as there was little time and the pieces were on view in the galleries. The cursory look revealed minor damage to a number of artifacts such as splits, tears, cracks, cupping (see images below). These condition issues are not unusual for items of these types and are generally consistent with the age and use of the collections. Overall the exhibition and storage conditions at the Philbrook have made sound efforts to integrate best practices in collection care within a challenging historic structure.

Based on the "proofed fluctuation" model, the Philbrook's collections have already been subjected to substantial deviations from tight humidity control. Any damage that happened has already happened and therefore deviations up to that previously sustained level will not result in additional damage. This would be easier to document in the future with better documentation on some of the more sensitive 3-D collection items. It should also be noted that within the conservation field there is debate as to what constitutes damage, for instance does micro-cracking of varnish or paint layers only visible under the microscope count? Or should damage primarily be considered as problems visible to the naked eye?

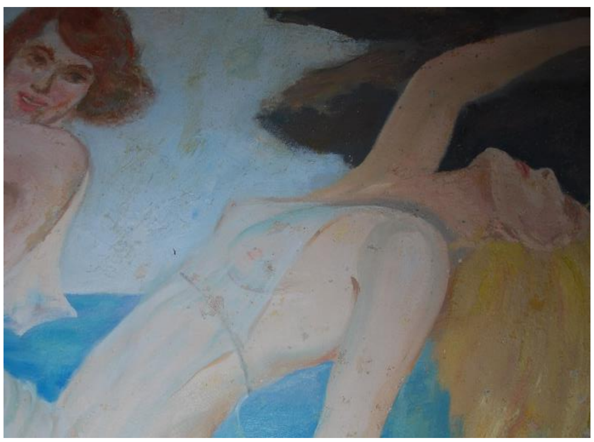
The 2002 CAP report documented that 95% of the collection was cataloged and inventoried. More recently the Philbrook purchased the TMS collection database. However, it seemed in conversation with Philbrook staff, that there is not good documentation of condition either with digital images or written reports. Without thorough documentation of the condition history of these artifacts it is impossible to determine the cause of deterioration or whether any of the issues noted in pictures or in person may have been prompted or exacerbated by environmental conditions. Ensuring that there is good condition reporting for items beyond the Kress collection paintings should be a future goal of the collection staff.


Chair with stretched hide (overall on left) showing splits and tears possibly (detail on right)


African headdress with radial splits in the wood

Deteriorating linen mummy bundle wrappings

Cracking and loss of lacquer surface



Loss of surface on painted wall - main floor

Cracking and tenting of painted surface – lower level

The items chosen as representative of the collection each have different risk factors for the various methods of decay and agents of deterioration described above.

- For items such as the Native American feathered basket (#1942.14.1900) and the Quiver (#D-11), light, pest infestation and physical forces such as deformation are greater issues than temperature and/or RH.
- For the African headdress (#1974.5.4), Egyptian polychrome figure (#1974.23) and rawhide and wood chair (#1942.13.68), fluctuating humidity might have an effect on the hygroscopic wood and stretched hide but is unlikely to result in new cracking unless the changes are severe and sustained.
- The gelatin silver print (#2015.6.103) would benefit from cooler temperatures

- The oil paintings on canvas appeared to be in generally good condition while the painted canvas mounted onto the plaster wall showed issues that may be the result of visitors' hands more than environmental factors.
- The oil paintings on wood panel constitute some of the most sensitive items in the collection, in part because their condition has also been modified by numerous interventive conservation treatments. The judgement by Conservators Dianne Modestini and Shuan Kuang is that "the majority of the paintings on panel historically developed lifting paint and blisters, which had been repeatedly consolidated during numerous campaigns from the 50s to 80s (and a few in the 90s). The consolidants ranged from aqueous adhesives to wax. Many panels had been recommended to never be loaned. However, the paintings have faired [sic] extremely well in the recent decades. I did not observe active or recurring flaking, not even on the worst offenders. The panel supports and paint layers appear to be stable in their current environment"[28] Micro-climate framing could be a viable option for protecting some of these pieces from fluctuating RH on exhibit or for loan. It is the role of the painting conservators to specify the conditions needed for these pieces but their stability under current climatic conditions at the Philbrook is encouraging and fits in with the research of conservation scientists mentioned here in the report.

ENVIRONMENTAL RECOMMENDATIONS

Discussions by the project team recognize that exhibiting the collection by type, i.e. photographs in one gallery, watercolors in another, and panel paintings in a third, is not conducive to the programming and educational goals for the museum. Exhibitions are generally thematic or cross-cultural and will involve a mix of different types of artifacts. Therefore, while it would be ideal to be able to match different types of collections with particular spaces within the museum, this is not a realistic goal. Careful attention to whether a better match between environmental needs and space conditions may be possible for storage. Michalski concludes that rather than having simple specifications and high, unsustainable costs, it would be better to have complex specifications for various types of materials or artifacts and sustainable costs.[29]

Generally, it should be understood that:

1. Exhibition and storage conditions should be different for optimal energy and preservation reasons. Loan items may require specialized conditions.
2. Conditions in any particular space may not be ideal for all collections and therefore microclimate solutions e.g. vitrine with silica gel, passpartout, cabinets or boxes for buffering may be needed.
3. If microclimate solutions are implemented, careful consideration must be given to materials chosen for construction. In order for a vitrine with silica gel to be effective, it must be reasonably airtight. Off-gassing in an airtight microclimate can cause extensive damage to

[28] S. Kuang email communication 11/26/2018
[29] CCI website - https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html#tft2a (November 2018)

certain types of materials. A desire to mitigate one type of environmental damage (e.g. fluctuating RH) should not result in unintentional damage by another type (i.e. pollutants). A fuller discussion of pollutants as an Agent of Deterioration is outside the scope of this report but further information is available in Pam Hatchfield's 2007 book *Pollutants in the Museum Environment* and the AIC wiki[30].

Recommendations for Temperature at the Philbrook

"Sustained high temperatures have a much more significant impact on the stability of materials than do temporary spikes or wide fluctuations of temperature."[31] When determining appropriate temperature setpoints for the Philbrook collections, a balance between environmental sustainability, human comfort and the needs of the building may take precedence and these needs may outweigh the preservation needs of the collections. These factors will most likely constrain temperatures to a moderate range that will be generally appropriate, even if not optimal, for collections. Greater preservation for most items can be achieved by keeping storage areas cooler than comfortable for humans. Increased use of off-site storage may be advisable if this allows for collections to be kept in cool conditions. IPI's table on *Suitability of Storage Environments for Collection Materials* is a useful guide for understanding what temperatures will extend preservation for various types of collections.[32]

SUITABILITY OF STORAGE ENVIRONMENTS FOR COLLECTION MATERIALS

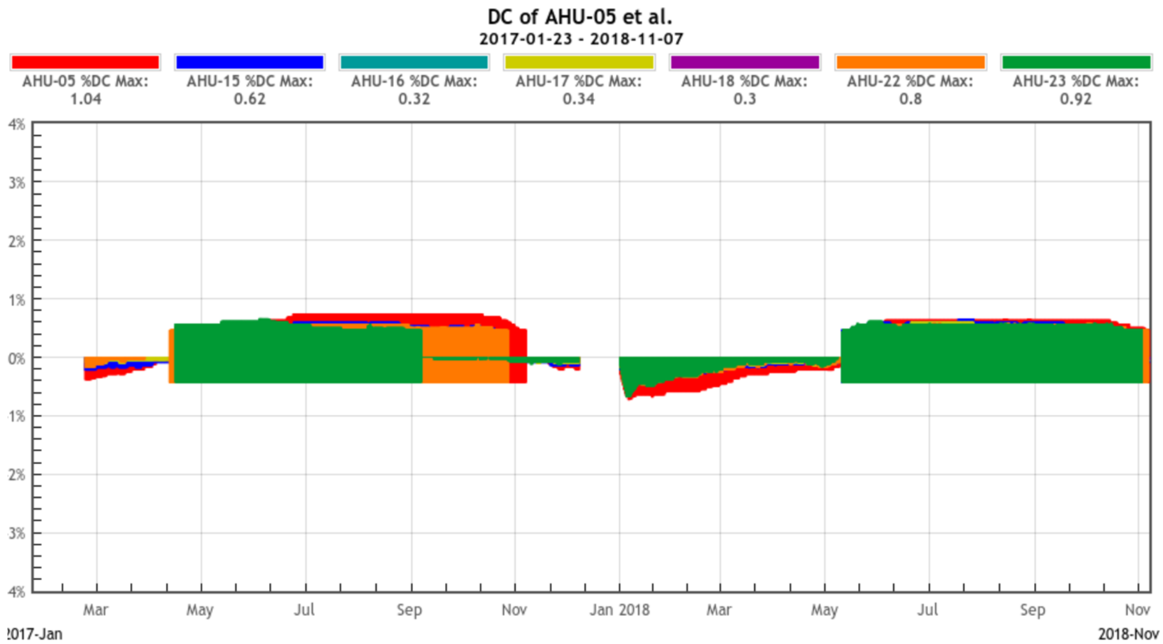
STORAGE CONDITIONS 30-55% RH	INORGANIC 3D OBJECTS	ORGANIC 3D OBJECTS	MAPS & MANUSCRIPTS	BOOKS	RARE BOOKS	B&W PHOTOS	FILM & COLOR PHOTOS	TEXTILES	PAINTINGS	AV MEDIA	ART ON PAPER
ROOM 68°F TWPI ≥ 45	Fair	No	No	Fair	No	Fair	No	No	Fair	No	No
COOL 54°F TWPI ≥ 120	Good	Good	Good	Good	Good	Good	Fair	Good	Good	Good	Good
COLD 40°F TWPI ≥ 350	Good	Good	Good	Good	Good	Good	Good	Good	No	Good	Good

RATING SYSTEM	
No	Unacceptable Risk
Fair	Some Risk
Good	Best Practice

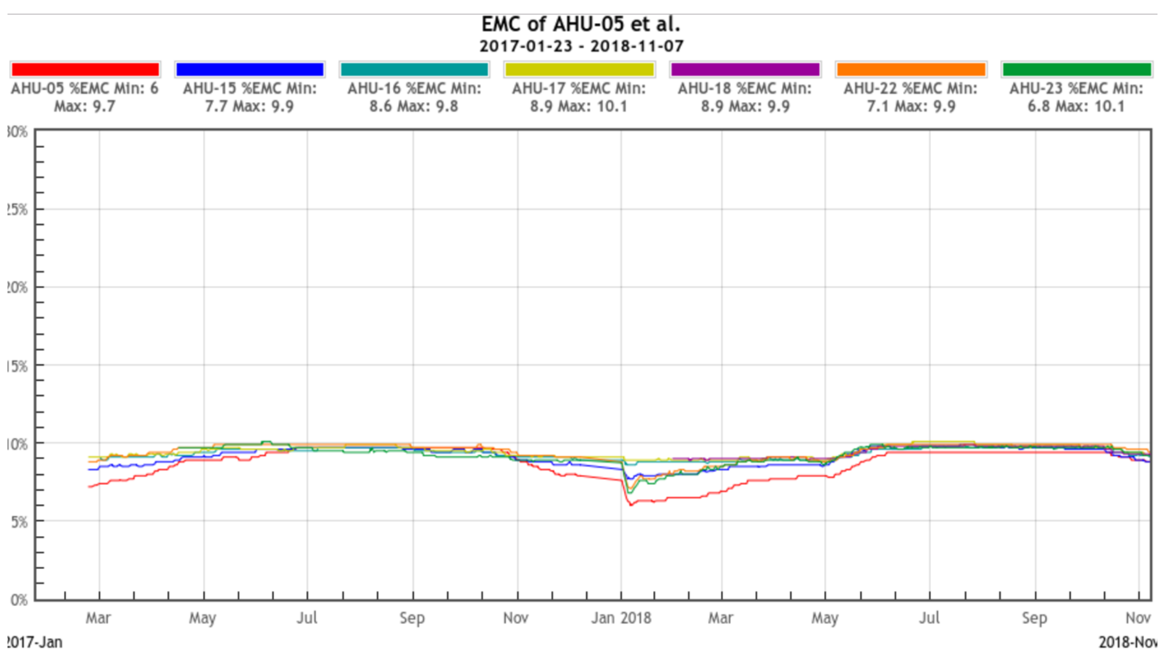
Recommendations for RH at the Philbrook

"Periods of sustained high humidity in the summer and sustained low humidity in the winter are more significant in terms of preservation than sudden or short term fluctuations in RH."[33] Because various materials are sensitive to RH in different ways, for a mixed collection such as the Philbrook's, the challenge is finding a range that minimizes the risk for the most materials. In looking at the previous year's data the conditions were generally within acceptable ranges. The galleries generally have %DC and %EMC results that are "OK" or "Good" according to IPI's metrics. IPI's mold algorithm show a low risk for mold outbreaks in most spaces.

[30] AIC wiki: Choosing Materials for Storage, Exhibition & Transport http://www.conservation-wiki.com/wiki/Materials_Working_Group
[31] IPI, 2012, p.14.
[32] IPI handout, 2015 https://www.imagepermanenceinstitute.org/webfm_send/759
[33] IPI, 2012, p.15.

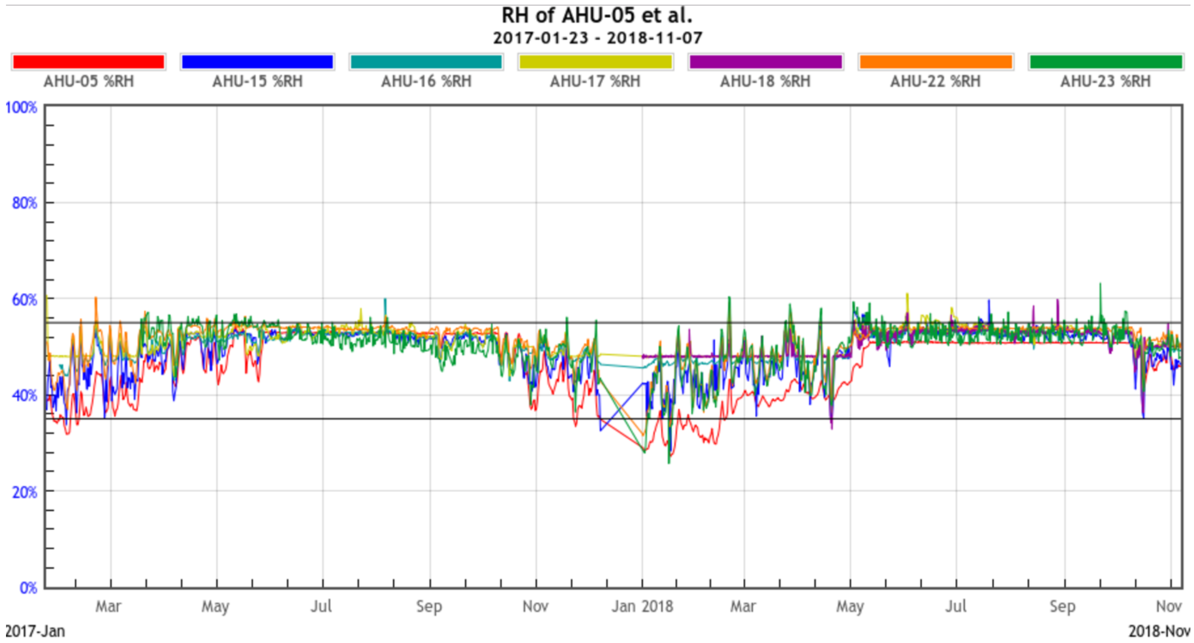


% Dimensional change metric for selected upper and lower floor galleries



% Equilibrium Moisture Content metric for selected upper and lower floor galleries

Excursions above 55 were short in duration and not likely to cause damage. The sustained excursions below 40% RH in the winter might not be a problem assuming that the collection has acclimated to drier conditions. Depending on energy savings and implications for the building envelope the 40-60% RH or, 35-55% RH ranges could be used.



Upper and lower floor galleries graphed with the bands of 35-55% RH indicating that the current system is able to achieve these conditions in most spaces.

As referenced above in the section on RH with specific needs, there are several categories of collections that may require more specific or highly controlled environments. Of particular relevance to the Philbrook are archaeological ceramics, glass and metalwork.

- Pottery may acquire salts in the ceramic fabric either through manufacture or during burial. The specific salt compound is relevant as different salts deliquesce (i.e. go into solution by absorbing moisture from the air). If the environment fluctuates above and below the salt's deliquescence RH then salts can be pushed into and out of solution in the ceramic fabric which can cause spalling, pitting and loss of surface.
- Some trade seed beads typically used on Native American artifacts can become unstable due to their chemical composition. The glass may "*sweat* when the RH is above a critical RH (~55% RH) because fluxing compounds in the glass deliquesce, on the other hand they *crizzle* when the RH is below the critical RH (~40% RH) that causes dehydration of other compounds in the glass. The gap between these two critical RH forms the safe range for these unstable glasses."[34]
- Archaeological metals such as artifacts found in the Antiquities and Native American collections have specific RH needs. Copper alloys (e.g. bronze) are generally advised to be held in low RH conditions e.g. under 30 or 40%. The restrictions are greater for archaeological iron-alloy which benefit from being in a dry environment under 20% RH. Overall the dryer conditions documented over the past year work well for metals and are appropriate for modern bronzes. eCNB gives an "OK" or "Good" rating to most spaces for their metal corrosion metric.

[34] https://www.canada.ca/en/conservation-institute/services/agents-deterioration/humidity.html#tft2a (November 2018)

Recommendations on Lighting at the Philbrook

Recommended practice in the museum/historic home community for acceptable level of light required for viewing collections on exhibit, based on experience and a number of studies is given below. The underlying logic behind these numbers is that any level of light in excess of the minimum amount necessary to adequately view an object on exhibition causes unjustifiable damage.

The Philbrook is using LED lights overall. While providing an energy and cost savings, LEDs also provide a preservation benefit as they do not contain damaging UV light. However, if the Kress Galleries are returned to their more original use (e.g. porches with greater airflow and natural light), then careful consideration will be necessary to ensure that collections not sensitive to light damage are selected for these areas. In general, collections of bronze and stone sculptures would be considered non-light sensitive. Much of the ceramic collection would also be low-sensitivity. An exception to this would be ethnographic ceramics with non-glazed painted decoration, e.g. carbon-based pigments/paints used to decorate some Native American pottery as fading in these types of artifacts has been documented.

Levels of Susceptibility to Light Damage & Types of Materials	**Recommended Levels of Illuminance**
Category 1: Most Susceptible e.g. textiles, cotton, wool, silk and other natural fibers, most paper-based materials, watercolors, fugitive photographic images, most organic-based natural history specimens, fugitive dyes, watercolors, some minerals.	50 lux (5 foot-candles)
Category 2: Susceptible e.g. high-quality paper with light stable inks such as carbon black, modern black and white gelatin silver photographs, textiles with stable dyes.	100 lux (10 foot-candles)
Category 3: Moderately Susceptible e.g., oil and tempera paintings, bone, ivory, wood finishes, leather, some plastics.	200 lux (20 foot-candles)
Category 4: Least Susceptible Least susceptible displayed materials: metal, stone, glass, ceramic, most minerals and inorganic natural history specimens.	Dependent upon exhibition situation.

RESOURCES

IPI's Guide to Sustainable Preservation Practices for Managing Storage Environments
https://www.imagepermanenceinstitute.org/store/publications/sustainable-preservation-practices-guidebook[35]

IPI's Methodology for Implementing Sustainable Energy-Saving Strategies for Collections Environments
https://www.imagepermanenceinstitute.org/resources/publications/ipi-methodology-guidebook[36]

IPI, *Climate Notes* e-newsletter excerpts http://www.ipisustainability.org/resources/

- A Brief Overview of Temperature and Moisture Equilibration
- Summary of the Museum Preservation Summit
- Planning for HVAC System Renovation
- Energy Savings and the Preservation Environment
- Drawing the Line on Acceptable Relative Humidity Fluctuations
- Seasonal Extremes Matter
- Managing the Storage Environment – Current Thinking
- Making Cultural Institutions Sustainable
- Energy-Saving Options to Consider
- Balancing Stewardship and Sustainable Practice
- Equilibration: Rates and Responses to Environmental Changes
- The Who, Why, When and How of Moisture Equilibration
- Understanding Dew Point
- Why is Dew Point Important for Managing my Environmental Conditions?
- Winter Dryness and its Effects on Collections
- Tell Me What You Want: Specifying Storage Conditions for Collections
- Energy Savings & Collection Management

Sarah Stauderman, William G. Tompkins (eds), 2016. *Proceedings of the Smithsonian Institution Summit on the Museum Preservation Environment.* Smithsonian Institution. doi: 10.5479/si.9781935623878
https://opensi.si.edu/index.php/smithsonian/catalog/book/111

Thomson, Gary, 1986 (2nd edition). *The Museum Environment*. London: Butterworth Heineman.

[35] Available in Project Fileshare
[36] Full text download available online

APPENDICES

1. 1a. Philbrook Museum listing of Air Handling Units and areas served and 1b. AHU map
2. Image Permanence Institute's Environmental Risk Ratings
3. eClimateNotebook reports in several formats: comparison of IPI metrics, comparison of statistics, overview reports and two sets of performance reports (one using 45-55% RH for measuring system performance and the other using 40-60%) for Philbrook environmental data for the following spaces:
    a. Lower Level
        i. AHU-05 – Lower Level Storage
        ii. AHU-22 – Native American Galleries, Bowling Alley Gallery
        iii. AHU-23 – Santa Fe Room, Spotlight Gallery
    b. Main Level
        i. AHU-21 – Kress Gallery
        ii. AHU-25 – Kress Gallery, Italian Sculpture
        iii. PEM2-16108 – Kress Gallery
        iv. PEM2-16109 – Kress Gallery
        v. PEM2-17049 – Kress Gallery
        vi. PEM2-17489 – Helmerich AHU-12
        vii. AHU-19 – Library, Music Room
        viii. AHU-20 – Dining Room, Great Hall, Living Room
        ix. AHU-08 – Rotunda
        x. AHU-14 – Salon Gallery, Breakfast Room, Hallway
    c. Upper Level
        i. AHU-15 – Works on Paper Gallery
        ii. AHU-16 – African Gallery, Antiquities Gallery
        iii. AHU-17 – American & Contemporary Galleries
        iv. AHU-18 – Contemporary Craft Gallery, Waite's Bathroom, Waite's Bedroom
    d. Misc.
        i. AHU-04 – Restaurant
        ii. AHU-13 – Elevator lobbies
4. Image Permanence Institute's Summary of Suitable Storage Environments for Collection Materials
5. List of representative Philbrook collection items
6. "Temperature and relative humidity specifications for mechanical control systems in museum buildings, showing their risks and benefits to various collections" 2007. Stefan Michalski, CCI

National Endowment for the Humanities, Sustaining Cultural Heritage Collections

Reporting on 12/4/2018

To Rachel Keith, Philbrook Museum of Art

From Sarah W. Sutton, Sustainable Museums

This broad-based group came together for an important kickoff meeting to see the building, understand the project, and begin mapping out the learning needs and decision-making process for the team. During all our discussions, Rachel or I took care to point out any great discoveries, non-negotiables, and project values that came to light during discussions. These included

Recognition of

- The nothing-short-of-heroic work to date to keep 20 – 30-year-old equipment running
- The critical sensitivity of the Kress Collection of panel paintings AND the lack of change in condition of time
- The importance of an integrated approach for developing a complete understanding of current conditions, awareness of professional and technical developments since the systems were installed, and a well-informed approach to solutions

Understanding of

- The science behind changing approaches to expectations for environmental management: shifting from 70˚/50%Rh to wider ranges for acceptable conditions for many objects and the clarifications of differing needs for differing objects.
- The value of the structural history of the house and the growing interest in returning more closely to its original appearance and use when appropriate

The most important aspect of our strong first meeting was grappling with the growing realization that there would be no clear or straight-forward solution to identifying a more sufficiently sustainable way to manage the Kress Collection wing for the collection needs. We left the meeting expecting to do so, however.

The team identified needs for building probes to understand more of the structure, and was quite concerned aesthetically about the exterior windows and the problems they contribute to management of the interior spaces. For example, the temperature and humidity difference from one square foot section to another could vary greatly given the structure of the wall section or the existence of a window.

The team addressed many other distinct issues and developed an understanding about how needs and opportunities might be wrapped into final decisions. These include the new front entryway (a rotating door or something more attractive?), whether or not to group collections by type? (no), and past changes to the HVAC system and how they affect current operations.

During the second team call/meeting, we discussed how, during the months after the initial meeting, the institution completed some planning affecting the building and fundraising. The results created an opportunity to think differently about the space, perhaps not to have it as a location for art, or most sensitive art, and to return it more to its original use as an area often open to the gardens. As a result, the team concluded we may not need to find a more sustainable approach to exhibiting such sensitive objects in this space, and that, by relocating them, we can design an approach that is less invasive to the structure and more tailored for the objects. And though all galleries will include a range of objects, it is likely that only one, smaller area will need the tighter, more energy-consuming capabilities.

The team also discovered two unexpected efficiencies that improve sustainability:

- Saving money and materials by refurbishing some equipment that had been so well-serviced during their lifetimes as to make this possible
- Exploring ice block technology to make ice for cooling during the late night and early morning hours when utility costs are low (as is demand), allowing the ice to passively provide cooling during the balance of the day.

During the third team call/meeting we had an excellent update from Rachel Arenstein, consulting conservator, on object conditions. She shared and interpreted environmental monitoring information that was very instructional for all. During the group discussion of the data we discovered a potential location issue for some dataloggers that will be reviewed to be sure the base of data for recommendations is as we intended.

We left the meeting with an excellent foundation for next steps as we get ready for future work. In addition to the deliverables this project will produce, the most valuable results include a raised awareness among all members of how and why this process works, and how it changes museum practice for the better.

Comments

Reviewing the need for change: The goal of such a project is to think differently. By taking all the good stuff we know, and all the lessons we have learned, and adding to them a new perspective that allows us to build on past work, we can successfully respond to new realities and demands.

The need to think differently has arisen in response to decades of quiet, often unnoticed change. The professional expectations for collections care, and the institutional expectations for performance, were very different when these systems were installed. Four differences stand out:

- The economy was more comfortable for art institutions decades ago
- Energy was less expensive
- Few people anywhere were aware of the environmental impacts of any energy use on the environment in climate, and none to the level we now have
- And no one understood the existence of physical variability in objects' needs, or the impacts of so many physical and biological stressors on objects, in a museum setting

In thirty years, we have come to understand and experience nearly everything about museums and museum operations differently (education, board management, gift shop finances, human resources, and collections management). One aspect that has remained comparatively stable is the physics involved in manipulating conditions.

However, the developments in systems allow us to manipulate conditions more accurately and acutely, and monitoring conditions now allows us to be more informed about the results of manipulating conditions and, in turn, more informed about how our systems are able to manipulate conditions. We also recognize that even as we are having increased difficulty affording energy for our collections care and therefore must find ways to save money, we also now know that museums' significant energy consumption damages the environment and climate in ways that harm life on the planet at a large scale. That realization creates an obligation for a community-minded, charitable and educational institution to limit its negative impacts. In the face of those shifts in understanding and responsibilities, we began this search for new approaches.

Review of the experience: How this project reflects a sustainable approach.

Though no one could have expected an institutional course-correction such as the one to shift the use of the Kress Collection gallery, this kind of shift often happens in projects that value consideration of new approaches.

This project was triggered because of concern for care of the collection – due to its characteristics and to the age of the HVAC system. While you examined how to address current concerns and fold them into plans to upgrade systems quite at the end of their lives, you were willing to consider some shifts in the building. Then the team discovered an even larger potential change – from outside the project – and adapted to it.

None of the solutions you were exploring was easy or obviously superior to the others. Then a new opportunity began to develop. It was interesting and worth considering because the team had already encountered challenges and was still searching for the best solution. The new option, to stop trying to make the systems do something that was incompatible with the room is a more sustainable option. The process worked: it primed you to see a new opportunity when it was presented. The process also created the opportunity to examine it and fold it into your thinking with the professionals on hand and prepared when it arose.

A Final Thought: Raising or strengthening awareness, knowledge, skills and abilities in sustainability during a grant project – notes to myself for future projects.

Because sustainability thinking is a new skill for many folks, and an evolving skill for all of us, you can expect that, during the project, team members and observers will have the opportunity to mature in their understanding, support and implementation of sustainability choices in general, and specifically with the grant project. To me this means every conversation is a way to move someone to a new level, whether that movement is small or large and directly related to the grant outcomes. For example, when a team member is not already incorporating these practices into his or her work, grant participation at least raises awareness of these practices and creates the opportunity to consider how those new ideas align with existing ideas, and then if/how/when to begin shifting practice on other projects now or in the future. For those who are already aware, this is an opportunity to continue to develop awareness, knowledge, skills and abilities, and to share that with others. Since you will likely always have a mix of exposure and interest among participants, the most important first step is to establish some baseline understanding.

This is challenging, and I believe I should have emphasized this as the project began rather than address it as it developed. A half-day or full-day of my time spent with the staff on sustainability thinking and its role at the institution will simplify the project director's work throughout the project. During the team meeting, the risk of appearing heavy-handed (despite one's best efforts) is far more affordable than the risks of misunderstandings later on. In this case we worked on this challenge on a topic-by-topic basis which may have been easier and timelier if we'd covered more basics at the beginning.

For future team kick-offs, I would recommend a team orientation to sustainability (even as a repeat for staff). I will recommend 45 minutes in the kickoff meeting, for both planning and implementation projects, to:

- establish a shared understanding of the definition of sustainability
  - ask for generalized examples people are aware of or that they practice themselves
- describe why we're applying it to our work
  - this is an opportunity to try thinking differently, to take all that we each know now, that we have been building up for years, and mix it with new information and approaches, to produce an even better way of fulfilling our professional roles and responsibilities
- provide examples of a variety of sustainability approaches in similar institutions or settings
- explain the basics of sustainable thinking as it applies to museum projects
  - these new approaches are developing based on new research, technology, materials and applications
  - systems thinking helps anticipate future effects or results, and identify or compensate for unintended consequences (which may also be opportunities)
    - major challenges can be important opportunities
    - too much resistance or pressure will disturb any system and cause it to perform poorly (inefficiently), so when the struggle is great, it is time to step back and reconsider
  - systems-based choices and decisions have so many facets that it is difficult to anticipate them all
    - responsive solutions are highly influenced by local conditions– from a part of the building to a region of the country and more
    - adjacencies and timing can be used to improve efficiency
  - reexamining any practice is appropriate for reviewing and discovering efficiencies
  - piloting and testing save money, time, and struggle and so are important steps.
- review this project's general sustainability expectations and the role of an integrated approach to improve the applicability of sustainability solutions for this specific project
- ask everyone for their responses
- conclude by reviewing any non-negotiables and project values, identified so far, to help guide decision-making

I will also ask that with subsequent meetings, after any practical updates, that we call for any sustainability questions or ideas and concepts before continuing with planning and decision-making. That brief review will smooth the way for each meeting.

Philbrook HVAC Renovation
System Specs
January 25, 2019
DRAFT

Renovate HVAC system to the following specs:

Phase 1: Stabilize System

- Replace failing system components with high-efficiency, durable equipment
- Aim for stable humidity in the range of 45% +/-10 (winter) and 50% +/-10 (summer) and float temperature to keep humidity stable (instead of other way around)
- Always keep RH between 30 and 60%
- Maintain lowest level storage areas at 50-60 deg., galleries at 68-72
- Retain existing ductwork
- Employ a centrifugal chiller
- Rebuild and increase efficiency of cooling towers
- Restore redundancies throughout heating, cooling, and humidification systems
- Calculate makeup airflow by CO2 levels in the air and outdoor temp, not a static amount
- Maintain slightly positive air pressure in the building
- Assume increase of 15,000 sf spread over two levels, built with modern construction methods, including appropriate insulation, and stucco finish. New area would have windows facing north and east.

Phase 2: Adjust and Refine

- Increase efficiency overall
- Improve system controls to allow more flexibility / greater control by area
- Adjust ductwork where required
- Introduce humidity controls in all art storage areas
- Relocate ductwork from roof of Kress
- Replace blower motors in air handlers with multispeed motors for more efficient and precise system control (at least in three—1, 11, and…one other)
- Improve air filtration in the building--upgrade to MERV 11 air filters (or better?, if this is what we're currently using)
- Upgrade Building Automation System to support increased control / efficiency
- Implement recommendations to improve efficiency through operational methods

Key Considerations:

1. The primary goal is to increase efficiency as far as possible without endangering the collection or the building.
2. Stabilizing the humidity and allowing temperature to float (within reasonable parameters) is key to meeting the needs of the collection.

Summary of Recommendations Resulting from 2017-18 NEH HVAC Planning Grant
Philbrook Museum of Art

Recommendation	Lead Advocate
General	
Sustainability is a way of thinking. Include an intro to this in future projects.	Sarah Sutton
Complete a Master Plan for the building before proceeding with major alterations to the building fabric.	Jeff Baker
HVAC Recommendations	
Relocate ductwork from roof of Kress.	Jeff Baker
Retain existing ductwork.	Greg Sutcliffe / all
Hire a specialized and impartial HVAC engineering company to review all plans and oversee installation.	Guy de Verges
Replace blower motors in air handlers with multispeed motors for more efficient and precise system control.	Guy de Verges
Rebuild cooling towers (as they're high-quality and can be made more efficient during the process)	Consensus
Increase capacity for steam.	John Gwin
Plan to control humidity in collection areas not currently humidified: Rotunda, several storage rooms, and areas adjacent and open to humidified collection areas.	John Gwin
Re-establish redundancies within system.	All
Improve air filtration in the building--upgrade to MERV 11 air filters and tape in place to minimize air flow bypass.	Guy de Verges
Confirm condensate overflow alarms are in place.	Guy de Verges
HVAC System Settings	
Aim for lower temperatures in galleries (to human comfort; 68 deg. F is really too high for most objects).	Rachael Arenstein
Aim for lower temperatures in storage (54 deg. F).	Rachael Arenstein
Prioritize relative humidity stability over temperature (float temp slightly to support stable humidity.	Rachael Arenstein
Aim to keep RH above 30% and below 55-60%.	Rachael Arenstein
A range of 35-55% or 40-60% RH would be appropriate, depending on the needs of the building itself.	Rachael Arenstein
Ensure changes in humidity levels happen gradually. Ok to vary temperature somewhat.	Dianne Modestini
Keep RH above 35-40% in areas with panel paintings. (These paintings are likely accustomed to higher humidity levels).	Dianne Modestini
Maintain slightly positive air pressure in the building.	Greg Sutcliffe
Increase system flexibility by supporting more precise independent control of various building zones (especially storage areas).	All
Calculate makeup airflow by CO2 levels in the air and outdoor temp, not a static amount.	Guy de Verges
Building Improvements	
Work with the building (not against it).	Consensus
Probe building to identify sources of mapping / damage.	Jeff Baker
Commission AutoCAD drawings of building.	All
Ensure the sprinkler system isn't spraying the building. The limestone columns are porous and can wick moisture into the building interior.	Guy de Verges
Trim vegetation at least 18" from building (and check quarterly to ensure this is maintained).	Guy de Verges
Remove irrigation heads from near the building. Review spray patterns quarterly.	Guy de Verges
Consider applying an appropriate waterproofing sealer to the columns' exterior.	Guy de Verges
Ensure porous building materials (i.e. drywall, wood) don't come in direct contact with the columns in any redesign. Install a nonporous thermal break.	Guy de Verges
Replace (non-historic) metal windows in sunroom areas with modern thermal windows with double / triple glazing and argon-filled air gaps and a coating to minimize solar heat gain.	Guy de Verges
Remove the interior coverings from the Kress window openings to evaluate for moisture damage.	Guy de Verges
Install interior ventilated wooden storm windows with UV protection and low-E / similar coating on all wooden windows in Villa.	All
Remove old coatings and exterior storm windows.	Guy de Verges
Inspect all wooden windows for caulking / painting needs.	Guy de Verges
Further inspect active leak noted at NE corner of Santa Fe Room.	Guy de Verges
Evaluate further whether insulating attic would be appropriate.	Guy de Verges
Replace seals in revolving door.	Guy de Verges
Seal other entry doors / points of conditioned air loss.	Guy de Verges
Encourage use of revolving door by installing signs.	Guy de Verges

Inspect door seals quarterly.	Guy de Verges
Investigate PSO's Power Forward Program.	Guy de Verges
Complete the switch to all-LED bulbs in galleries.	Guy de Verges
Begin composting waste from restaurant.	Guy de Verges
Repurpose Kress Galleries from tightly sealed gallery space for the most sensitive items in the collection to a more versatile, flexible space closer to its original design.	Museum
Environmental Monitoring	
Purchase additional environmental monitors (i.e. PEM2s) to support more comprehensive monitoring of actual gallery / storage conditions.	Rachael Arenstein
Maintain good digital images and condition reports for more of the collection, including "canary objects" that would serve as early indicators of dangerous conditions.	Rachael Arenstein
Double-check dataloggers regularly using a handheld hygrothermometer.	Rachael Arenstein
Establish a program of regular calibration checks for all equipment / monitors / areas.	Rachael Arenstein
Ensure dataloggers are positioned appropriately.	Rachael Arenstein
Further evaluate whether artworks hanging on the sun-heated, uninsulated walls are suffering from the wide temperature fluctuations.	Guy de Verges
Collection Care	
For areas with higher light levels post-renovation, install bronze and stone sculptures, ceramics (with stable glazes / avoid non-glazed painted decoration), and glass.	Rachael Arenstein
Consider keeping art from directly touching walls / building fabric.	Rachael Arenstein
On walls in contact with limestone columns / other sources of moisture, allow an air space between wall and artwork.	Guy de Verges
Relocate the Kress Collection to other areas.	Museum